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SPECIAL ISSUE ARTICLE

Molecular Gastronomy: A Food Fad or an Interface for Science-based Cooking?

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Abstract A review is given over the field of molecular gastronomy and its relation to science and cooking. We begin with a brief history of the field of molecular gastronomy, the definition of the term itself, and the current controversy surrounding this term. We then highlight the distinction between molecular gastronomy and science-based cooking, and we discuss both the similarities and the distinctions between science and cooking. In particular, we highlight the fact that the kitchen serves as an ideal place to foster interactions between scientists and chefs that lead to benefits for the general public in the form of novel and high-quality foods. On the one hand, it can facilitate the implementation of new ideas and recipes in restaurants. On the other hand, it challenges scientists to apply their fundamental scientific understanding to the complexities of cooking, and it challenges them to expand the scientific understanding of many chemical and physical mechanisms beyond the common mass-produced food products. In addition, molecular gastronomy forms an ideal base to educate the general public about the basic principles of science and cooking and how they can be utilized to improve the awareness of the role of food and nutrition for the quality of life.

Keywords Molecular gastronomy · Science-based cooking · Experimental cuisine · Quality of life

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Introduction

This article provides a short summary of a half-day session on "molecular gastronomy," which was part of the "Second Symposium on Delivery of Functionality in Complex Food Systems," held at the University of Massachusetts at Amherst (Amherst, MA), in October 2007. We give an abbreviated history of molecular gastronomy and its current status as presented in that session and a summary of the discussion on the topic held between about 70 scientists, both from the academia and industry of whom several are involved in collaborations with chefs in restaurants. This article is meant as a general introduction to the articles on molecular gastronomy in this special issue of "Food Biophysics." We close this article with a perspective on future opportunities for combining food science with gastronomy.

A Short History of Molecular Gastronomy

The importance of utilizing the scientific method to understand food properties was recognized as early as in the seventeenth century (1783) by Lavoisier and half a century later, e.g., by Brillat-Savarin in his monograph "Physiology of Taste" (1825)[1,2]. Brillat-Savarin defined gastronomy as "the reasoned study of all that is related to man as he nourishes himself." He also gave the field of gastronomy a practical purpose namely, "to keep human kind alive with the best possible food." A scientist who in more recent times emphasized the link between gastronomy and science was Nicholas Kurti, a low-temperature physicist at Oxford University in the UK. In 1969, Kurti held a presentation entitled "The Physicist in the Kitchen"[3], and this was recorded by the British Broadcasting Corporation. A well-known quote of him is "It is a sad reflection that we know better the temperature inside the stars than inside a souffle." A more recent term that invokes the relationship between science and gastronomy is "molecular gastronomy," which has been defined as "a branch of science that studies the physicochemical transformations of edible materials during cooking and the sensory phenomena associated with their consumption"[4]. It is interesting to note that the term is an abbreviation of a more extended term "physical and molecular gastronomy." This latter term was the title of the first symposium on the science of gastronomy, organized in 1992 in Erice, Italy, with the involvement of Elisabeth Thomas, Nicholas Kurti, Hervé This, and Harold McGee as an invited guest director. The symposium was meant to bring together scientists and chefs and has been continued every 2 years until 2005.

In general, the field of molecular gastronomy may be considered as that part of food science that focuses on home and culinary eating transformations and culinary phenomena (together known in our times as "gastronomy"). A good contemporary example of a systematic analysis and compilation of fundamental knowledge on cooking, accessible to the general public, can be found in the monograph by Harold McGee, entitled "On food and cooking: the science and lore of the kitchen," with its first edition in 1984[5]. Previous work in this direction had been undertaken in particular by the French scientist Edouard de Pomiane[6,7]. In 1988, Hervé This published a book entitled in French, "Casseroles et Eprouvettes"[8], recently translated into English as "Molecular Gastronomy"[9], and in recent years, several books on the topic have appeared[10,11].

The scientific program of molecular gastronomy has been recently reformulated by Hervé This[12] and is to explore scientifically: (a) the technical part of cooking, i.e., the science behind recipes (applying the concepts of precisions, referring to details in a recipe, and definitions, referring to the main points in a recipe), (b) the artistic component of cooking, and (c) the social component of cooking. This presentation was made at a molecular gastronomy session of the Euro Food Chemistry meeting in Paris, August 2007, which defines the first time that molecular gastronomy was included as a symposium topic at a scientific conference[12].

The technical component refers to craftsmanship (repetition, tradition, well-executed work), whereas the art component refers to more creative aspects (innovation, creativity, expression of beauty)[13]. We should stress that craftsmanship also benefits from a better physicochemical understanding of cooking. Hervé This has also stressed the educational potential of molecular gastronomy in its ability to demonstrate the contribution that science makes to society[14].

There is obvious intuitive understanding regarding many culinary transformations, but the question is whether these phenomena appeal to fundamental issues. Another question is whether a food scientist should be concerned at all by these matters. In addition, because cooking has seldom been taken seriously by scientists, a general framework to scientifically address issues relating to cooking has been effectively lacking for some time, although works of de Pomiane[6] and the previously mentioned contemporary monumental work of McGee "On Food and Cooking" have appeared.

Regarding cooking, one may differentiate between traditional versus creative approaches. Whereas the first is primarily concerned with the lore of cooking and often involves highly specific but often unsubstantiated recipes, which function only in a narrow context, the latter approach is based on innovative and creative ideas. As, however, most chefs lack the basic understanding of the principal physical and chemical transformations during cooking, creative cooking often ends up being implemented by trial-and-error rather than being guided by fundamental insights.

As creative cooking is often dealing with novel combinations of ingredients and preparation methods, it is more open to a scientific approach than traditional cooking is. As any science, the science of cooking should be hypothesis-driven and should focus on fundamental insights and mechanisms specifically relevant for cooking. Another important aspect of a scientific approach to cooking is that its practitioners should aim to understand the vision of chefs on ingredients and food, even though they are usually nonscientific and sometimes irrational, to be able to communicate with the chefs, and to be able to translate scientific concepts into practical guidelines. An excellent example of a hypothesis-driven approach to cooking is described by Harold McGee in his book "The Curious Cook"[15]. For example, in this book, it is described how the cooking time of a steak should depend on the thickness of the steak and the form (cube or cylindrical for example), using results of heat-transfer equations, while subsequently, these relations are experimentally tested in the kitchen. Other good practical examples of a successful interplay between science and gastronomy can be found in the work of Ferran Adria in his restaurant el Bulli, where art and science are systematically blended together and, more recently, the foundation Alicia, near Barcelona (see http://www.elbulli.com/cronologia/index.php?lang=en). Another example is the successful collaboration between the three-star chef

Heston Blumenthal and the physicist Prof. Peter Barham of Bristol University and between Heston Blumenthal and the food scientist Prof. Andy Taylor (Nottingham University), who share a Ph.D. student together. The collaborations have been successful from an education point of view as well as a research point of view. Yet, another example is the creative output generated between the chef Pierre Gagnaire in Paris and the scientist Hervé This.

The term molecular gastronomy has been used in the culinary arts and in particular by journalists to describe a cooking style adopted by certain chefs that is characterized by its reliance on principles, practices, and techniques superficially associated with the sciences and with food technology as applied within industry. The technology, however, has become, in unfortunately too many cases lately, the only driving factor for the development of a new dish, instead of striving for excellent food per se. In addition, it is this technology push that has aroused media attention with unfortunate consequence of stimulating one-directional thinking, with the consequence that quite a number of serious chefs that were originally associated with the term (as they experienced that science could leverage their creativity and help them in making good food) have now distanced themselves from it and have stressed that their cooking style is based on a quest for quality and excellence, rather than for novelty and gimmicks[16]. Therefore, their main idea is that one should not just use the science for the sake of novelty but science for the sake of getting excellent food. These chefs have stated that a scientific understanding of the behavior of foods during preparation and cooking is only one of the tools that they use in their quest for excellence. Consequently, they will collaborate with scientists and industrial engineers but also with professionals from many other disciplines such as architects and designers to explore the full expressive potential of food[16]. These chefs are thus open toward the understanding of the cooking process as provided by food science and to the various tools and working procedures derived from food technology. This development turns away from a superficial focus on technology and gimmicks. Conversely, it reemphasizes importance of the understanding of food, ingredients, and cooking methods. The understanding of cooking processes is for some chefs in fact the actual meaning of molecular gastronomy. This was articulated in fact by Moshik Roth, the chef of ‘t Brouwerskolkje, in The Netherlands (van der Linden, personal communication).

Definitions

Lately, quite some confusion and disagreements have arisen around the term molecular gastronomy. We believe that these mostly are due to a lack of clarity about its meaning. We therefore provide some definitions and closely related terms below to clarify this term and try to point out their interrelationship.

Molecular Gastronomy Molecular gastronomy may be defined as the scientific discipline that deals with the development, creation, and properties of foods normally prepared in a kitchen. It is therefore a subset of the more general field of food science and technology that involves the scientific study of foods and the application of this knowledge to improve foods. The necessity for this subfield was born out of a feeling “that the phenomena that occur during cooking were neglected in Food Science”[12]. Molecular gastronomy is characterized by the utilization of the scientific method to better understand and control the molecular, physicochemical, and structural changes that occur in foods during their preparation and consumption. The scientific method is characterized by careful observation, hypothesis formation and testing, controlled experimentation, scientific objectivity, and experimental reproducibility. The definition given above is therefore in close agreement with that given by the authors of the original term: “The scientific exploration of culinary, and more generally, gastronomical transformations and phenomena, as described by cooks or by culinary books”[17]. We add that “it is important to emphasize that molecular gastronomy is not a type or style of cooking,” which we quote from Vega and Ubbink[18]. For this comment on not being a style of cooking, see also Adria et al.[16].

Science-based Cooking Science-based cooking as a term was introduced recently by Vega and Ubbink[18] as “the conscious application of the principles and tools from food science and other disciplines for the development of new dishes, particularly in the context of *haute cuisine*.”

Experimental Cuisine This concept was introduced by the Experimental Cuisine Collective (New York City)[19] and encompasses a list of aims, of which we quote: “Contribute to a rigorous scientific understanding of the physical basis for cooking processes” and “Enhance understanding of the social contexts for cooking and the societal ramifications of new food technologies, flavors, and new dining traditions.”

Science-based cooking refers to an approach adopted by certain chefs to create novel kinds of foods or to put a creative twist on traditional foods. This approach is characterized by the willingness of the chefs involved to break with traditional ingredients and cooking procedures to create novel foods with new appearances, textures, or flavors. These chefs are willing to experiment with new ingredients and technologies to produce foods. Hence, one may contrast this kind of progressive approach to cooking, with a more traditional approach that relies on preparing foods based on well-established recipes. Having said this, chefs who adopt either the progressive or traditional approach are united in their desire to create high-quality foods that look and taste delicious and that satisfy their customers. It should also be mentioned that those chefs who are involved in experimental cuisine are not necessarily aware of the scientific principles that underpin the novel dishes that they are creating. Instead, it is the scientific approach in molecular gastronomy that may provide information that chefs can use to better understand the processes occurring during the creation and preparation of foods. This knowledge may be used to optimize ingredients or preparation procedures (the recipe) of particular foods, or it may be used to prepare innovative foods.

It should be noted that the term “molecular gastronomy” invokes mixed responses from scientists, chefs, and the public alike. The term was originally coined by scientists to highlight the importance of understanding the molecular and physicochemical processes that occur during the creation of foods in the kitchen. However, some scientists believe that molecular gastronomy is a pretentious or trivial term that has been given to a practice that has been carried out for many decades namely, food science. Many individuals working in the culinary arts find the term to be unrepresentative, unsavory, or even ugly, whereas others find it to be novel and invigorating[20].

Ideally, a term is needed that encapsulates the creativity, artistry, and craft of the chef, as well as the rigorous principles of the scientific method and that, at the same time, sounds agreeable to scientists, chefs, and the general public. The term “Kitchen Chemistry,” which was the title of a recent book by the chef Heston Blumenthal of the Fat Duck restaurant in England, seems to meet many of these criteria, though the term itself neglects the physical aspects of cooking. The term, however, seems to be more palatable for the general public than molecular gastronomy. However, we also should ask if a new term is needed at all to describe the practice currently called molecular gastronomy or would existing terms such as “food science” or “food chemistry” in the kitchen be sufficient. We believe that there is a need for a specific term since molecular gastronomy (or an equivalent term) does have a number of features that distinguish it from conventional food science. Molecular gastronomy may be considered to be primarily concerned with establishing the scientific basis of the quality and overall sensory experience of foods produced in small amounts that will be consumed relatively quickly and close to the place of preparation and where, next to ingredient costs, the manual labor required to prepare the food is a major factor (in contrast to industrially manufactured food). The current focus within the food science area is primarily on the economic production of large quantities of foods that must remain stable and safe for long periods during transport and storage, that must be convenient to prepare, that should (ideally) be healthy, and that must still look and taste (reasonably) good when consumed. The term molecular gastronomy therefore delineates the subject matter of study and the overall goals of the endeavor, even though the actual scientific concepts and experimental methods used in molecular gastronomy and food science are often the same.

We conclude that there are various points of view on how to connect science with gastronomy. The interactions between scientists, chefs, and other food professionals will substantiate these connections in various ways, and connecting the field of food science with gastronomy will undoubtedly enrich the field of food science as it is now and perhaps broaden it.

Role of Molecular Gastronomy: Bridging the Gap between Culinary Art and Science

One important role of molecular gastronomy may be its ability to help bridge the gap between art, craftsmanship, and science. The kitchen is a meeting place where chefs, who are normally characterized by their artistry, creativity, and craft, can interact with scientists who are normally characterized by their empiricism, rationality, and adherence to the scientific method. The overlap of science, craftsmanship, and art within foods may help to begin about a conversation between these traditionally different disciplines. This will help educate the public about the importance of adopting an integrated and holistic approach to human knowledge and experience.

Creative cooking and food science are different human endeavors, with one being characterized primarily by its creativity and artisanal character and the other by its rationalism. At the same time, successful scientists and chefs are united by their passion for achieving excellence in their chosen field. Scientists have a passion for discovering how things work at the most fundamental levels, whereas chefs have a passion for creating novel and delicious foods

The *chefs* involved in developing innovative foods are usually characterized primarily by their creativity—their ability to imaginatively utilize traditional and nontraditional ingredients and processing tools to create new food forms, combinations, and tastes. Currently, many of the nontraditional ingredients are long-forgotten species and types of vegetables, roots, tubers, seafood, and also herbs and spices uncommon to Western cooking (but well known in, e.g., Oriental cooking). At the same time, there is a very strong focus to use unusual products from the local region or *terroir*.

The scientists involved in studying the molecular and physicochemical changes that occur in foods are usually characterized primarily by their rationality—their ability to systematically breakdown a complex system into simpler parts whose behavior can be understood within the prevailing scientific framework. We want to stress at this point that a successful scientist requires a great deal of imagination to decide what to look at, what is the best way of accurately describing a complex system, which hypotheses or theoretical frameworks are the most suitable, and which analytical techniques or tests are most appropriate.

Both chefs and food scientists are passionate about foods, the former regarding the preparation of excellent food and the latter regarding the understanding of the food and being the first in elucidating important and novel physicochemical mechanisms.

Many food scientists and technologists use their understanding of fundamental scientific principles to design and fabricate novel structures within foods to provide functional properties, such as stability, taste, texture, appearance, or flavor. For example, food scientists often create tiny hydrogel beads within foods to encapsulate flavor components. These hydrogel beads have inspired some experimental chefs to develop innovative dishes, e.g., artificial caviar beads produced by controlled gelation of hydrocolloids. For example, Chef Ferrán Adriá of *el Bulli* in Spain has produced "apple caviar" by gelling small beads of apple juice/alginate solution using calcium, the general procedure originally being developed by physical chemists. Reversely, scientists are inspired by straightforward problems regarding food in every day life, such as the stability of an alcoholic beverage like Pernod, upon dilution in water[21]. Another example is the distilling in the restaurant kitchen of certain flavors from food-based liquids and the concentrating of them using Rotavap equipment widely used in chemical laboratories. The flavors can then be introduced into another food matrix. This development is currently, however, idea- and technology-driven, and as chefs lack fundamental knowledge about volatility, partition coefficients, and hydrophobicity/hydrophilicity of flavor compounds, it is difficult for them to rationally decide how to optimize the extraction process and how to control the release of the flavor compounds in the novel food matrix to which they have been added.

Food scientists often test the properties of the materials that they produce using a variety of sophisticated analytical tools, including microscopy and scattering techniques to measure structure and appearance, rheometers to measure texture, and gas chromatography to measure the concentration of flavor compounds. Scientists ideally do these measurements to confirm or refute theories and hypotheses and to construct relations between properties of ingredients and macroscopically relevant properties of the food matrix. Chefs are interested in many of the same properties, but they analyze them by probing the properties with their eyes, nose, mouth, and touch, and they are interested in these properties to know whether the food is ready for being taken to the next preparation step or to be consumed. Having said this, the final arbiter of food quality is always the human sensory system, and so the food industry also relies heavily on sensory testing of its products by either trained or untrained panelists. One area where highly trained sensory scientists are widely used in the food industry is in flavor houses, where trained individuals (so-called noses) help with the formulation, refinement, and testing of complex flavor mixtures. Trained chefs, who have a highly developed sense of the appearance, texture, and mouth feel of foods, can play a similar role in the development of new products within the food industry. Sometimes, a fast route toward the solution of a problem is by applying intuition and experience and not by data-crunching activities or theoretical analysis. Hence, a chef's intuition and experience of the influence of specific ingredients on taste and texture will be a worthwhile asset for product development.

The end goal of food technologists and chefs is often the same: the consistent creation of high-quality foods. Nevertheless, the goals and constraints are different. A chef is interested in producing a relatively small quantity of food for a small number of people in a well-controlled setting, whereas a food technologist is usually interested in mass producing large quantities of food for a large number of people who are distributed over a wide geographical area. Both parties are interested in delivering maximum quality but for different audiences and purposes, and, in addition, the attainable standards are quite different. However, food technologists could still learn a lot from the passion of chefs in their quest for the ultimate food quality and experience.

Chefs are involved in many of the same procedures and activities as scientists and technologists but with a different orientation. They carry out experiments in the kitchen with different ingredients, processing tools, and preparation procedures (e.g., temperatures, times, effect of agitation and stirring, and changes in composition) and carefully observe what kind of material is produced, what its properties are, and how reproducibly it can be produced. The chefs use a rational approach in selecting appropriate ingredients and techniques. This rational approach is, however, based on previous knowledge and experience and, as argued, not so much on a deep understanding of the fundamental properties of the ingredients and preparation methods. Scientists conversely use a rational approach that is based on generic and fundamental understanding of how matter behaves. In addition, a chef wants in the end to prepare (excellent) food, whereas a scientist is generally satisfied when he or she understands some fundamental aspect of a food. Consequently, whereas there are some similarities between the motivation and passions of chefs and scientists, the focus and approaches of both are therefore completely different. However, it is increasingly becoming clear that the combination can be highly synergistic and can stimulate culinary innovation. This is a clear example of something that has been pointed by Donald Stokes in general, i.e., that combining curiosity-driven research with user-inspired research stimulates innovation[22].

Food as Art

There is a distinct difference between the perception of chefs who are involved in progressive and traditional cooking, between the artist and the artisan. The paying customer in a restaurant serving traditional food is expecting the chef to prepare a meal that meets certain predefined expectations. The customer is in charge; they actively order a particular meal and expect it to conform to a specific expectation—if it is not, they may complain. On the other hand, the customer in a restaurant that focuses on innovative cooking is expecting to be challenged and entertained, with novel sensory experiences being at the center. Food preparation has become a form of art—with the meal acting as the medium of communication. Furthermore, science can help in realizing such art. Nevertheless, one has to be careful not to give all experimental cuisine the same label. Just as modern art comes in many different flavors (pointillism, expressionism, impressionism, surrealism, Dadaism, Pop-Art, postmodernism, etc.), so does experimental cuisine. Each meal should be appreciated and judged in its own right, and aspects of originality, quality, and relation to the origins and meaning of the food should be part of this. Nevertheless, the criteria for judging experimental cuisine are different than those for judging a traditional meal; in addition to desirable appearance, aroma, taste, and texture, there are also be other attributes such as creativity, surprise, and novelty. We note that most of the high-level and innovative restaurants blend innovation with tradition, art, and artisanal ways of preparing food.

Molecular Gastronomy and Education

Molecular gastronomy provides an excellent opportunity for improved communication and understanding between artists, scientists, students, and the general public. The dissemination of knowledge from academia toward other educational bodies, as well as the transfer of knowledge and skills between their various levels, works in various ways.

First, is that the way of thinking of scientists can be introduced to chefs. An example is Harold McGee who actually does that in his courses at the French Culinary Institute in New York City. His approach in his lectures is that education is not based on the amount and/or type of knowledge that people acquire during a course but rather on getting them acquainted with a different way of thinking and approaching problems (McGee, personal communication, Autumn 2007). This different way of thinking may be referred to as hypothesis-driven thinking, together with solution-focused approaches based on generic knowledge instead of specific knowledge for a certain type of product or ingredient. The generic approach allows the chef to think of solutions for his desire to materialize his creative thoughts.

Second is that this type of thinking is also desirable to introduce to children at primary and secondary schools, and food is a wonderfully familiar subject to illustrate things. Hence, apart form introducing a valuable way of thinking, the use of the subject food automatically introduces knowledge that is essential for judging issues like health and food. This knowledge is essential for kids and adults alike and plays an important role in optimizing the choices people make in food eating behavior and thus may even indirectly aid food-related disease control. Examples of education in primary schools are available for example in France and The Netherlands (the latter country being subsidized by the government and chefs association). It is currently also undertaken by Alicia in Spain.

Third is that courses in food science that relate science with gastronomy and that cover various aspects of gastronomy are currently being taught or developed in several academic curricula (The Netherlands, Denmark). An example is a course on an MsC level at Wageningen University, which flourishes because of the collaboration with the Wageningen School for Chefs. Infrastructure is shared, which enables one to house more than 50 students in a professional kitchen for 1 week. Knowledge on the scientific (physico-chemical and chemical) background of recipes is shared with the creativity and taste-structuring desires from a chef's point of view. This bridges the material aspects of food with the perception aspects of food. The chef–scientist interaction is felt to stimulate educational developments at both academia and chef schools.

Fourth, is that the courses developed according to the above can easily be rolled out toward the public sector and industrial sector where appropriate.

Molecular Gastronomy: Who Benefits?

If molecular gastronomy is to continue to grow as a serious endeavor, then it must have strong advocates within a variety of communities, including scientists, chefs, the public, and the food industry. We list some ways that support of molecular gastronomy could benefit these diverse communities below:

Chefs: A better understanding of the processes occurring during the preparation of foods will enable chefs to optimize the selection of ingredients and preparation procedures (the recipe) of many traditional foods, as well as facilitating the preparation of new types of foods. For example, if a chef wants to create a novel foam that will last for a few hours, then it would help if they knew which ingredients and processes when used together can produce such a foam (e.g., hydrocolloids and proteins). Working with a scientist gives the chef opportunities that are seldom possible without this kind of collaboration, for example, access to processing equipment and analytical instruments (as a chef in Chile does while working with Professor José Aguilera). As argued above, it is important that chefs pick up a scientific way of thinking, i.e., a generic approach to problems rather than an approach highly specific to a particular context.

Scientists: The complexity, diversity, and dynamism of the natural and manufactured worlds by necessity mean that scientists must often focus on an extremely narrow field of study. A scientist may spend his or her whole live studying the properties of a single molecule or the characteristics of a particular chemical reaction. Molecular gastronomy brings science back into the real world, with all its complexity and subtlety. It forces scientists to put their specialist work into a broader context and helps them appreciate the wider importance of what they are doing. It fosters collaboration, communication, integration, and an appreciation of the limits of reductionism. It reveals questions and problems for further study that may otherwise not have become apparent. In addition, it encourages creative thought and thoughtful creation and respect for the origin and quality of foods. As one scientist during the meeting puts it: “It is so nice to see what the impact of science can be in such a direct way, to immediately see the benefit, instead of hearing about why a certain idea cannot be practically applied because of cost reasons for instance” (statement by Prof. J. Aguilera in[20]).

Molecular gastronomy provides a new focus for scientific research on foods—understanding the basis of quality in all its forms and using knowledge to produce quality, instead of focusing only on cost reduction. This provides interesting new challenges and topics to investigate. It also helps to foster an interest by the general public in scientific principles.

Food industry: The food industry could use the knowledge gained from molecular gastronomy to mass produce high-quality food for the general public at a reasonable cost together with a focus on originality and origin of foods and on added value. This perhaps could inspire the industry to look for interesting new developments on high-quality food grown and manufactured in a sustainable way. A new focus on food quality, sensory experience, and aspects of sustainability may also convince the consumer that it is worth paying a bit more for their food than they nowadays do, which could help to bring the negative spiral to an end of decreasing prices, shrinking profit margins for the industry, falling farmer incomes, and finally a drop in the quality of food products.

Society: The intersection of molecular gastronomy and the culinary arts is a natural meeting place of the “two cultures”: scientific rationalism and the creative arts. Food is a subject that everyone is familiar with and that everyone can relate to. On the other hand, few in the general public understand the scientific basis of food or are able to prepare artistic food creations. The intersection of human understanding and creativity in foods may help promote support for the general public for the arts and sciences in general. In addition, consumption of good food may be good for health and could help to reintroduce cooking skills now largely lost by most of the population. Whatever important trend regarding foods is relevant (reducing salt, sugar, and fat or providing enough food for the world using alterative protein sources, etc.) one always has the constraint that the taste should be good. Moreover, special foods are necessary for certain target groups that are going to play a growing role in society, such as kids, the elderly, and the ill. Food for these target groups does have special needs but always with the condition that it should taste good (which is now not always the case, in particular in the case of clinical nutrition). Interaction between chefs and scientists is probably essential for meeting the target of healthy food for each group together with the constraint of optimal taste. At the same time, due to the collaboration between chefs and scientists on healthy food, the results of such collaborations will be, almost automatically, effectively communicated in a way that is easily understandable by the main public. Yet, another important issue regarding the societal impact was put forward by another scientist: “It is a great opportunity for the dissemination of scientific understanding to the main public, which is one of the reasons universities are around in the first place” (statement by professor A. Foegeding in[20]).

Students: Programs get more focused on food as a whole and reemphasize the holistic aspects of food in studies, which up to now are heavily focused at purely rational and scientific approaches to food. Furthermore, students get more exposure to real problems related to foods. Provided that the balance between science and practical solutions is maintained, very interesting thesis subjects arise and stimulate the students. In certain cases, students may follow internships at places like Alicia.

The Future of Molecular Gastronomy

The future of molecular gastronomy will stand or fall with its ability to prove that it is a relevant scientific discipline or eventually a subdiscipline of food science. To prove this (and we as authors of this article are convinced that molecular gastronomy has a long-term scientific merit), a stimulus should be given to scientists to focus on food and food ingredients, with the aim of elucidating the basic physicochemical mechanisms of cooking. The results of these studies should serve several aims. First, as with all scientific investigation, its results should be communicated to fellow scientists by means of publications, conference presentations, and seminars and should be intellectually scrutinized by these fellow scientists. Second, a professional working relation should be built up with chefs, chef schools, and training organizations, and the scientific results should be translated in basic concepts and recommendations, which chefs are able to appreciate and master. Third, molecular gastronomy should prove its merit via its interaction with the general public and emphasize the importance of food and its preparation in the overall quality of life.

The traditional model of doing scientific research involves obtaining financial support for a particular project from government agencies or industry, carrying out the research, and then publishing the results in scientific journals. A scientist's reputation is built on the quality, relevance, and quantity of their research output. At present, there are few places for scientists to obtain external funding for molecular gastronomy research or to publish the findings of their research. Although already quite a number of papers have appeared on the subject itself and additional ones will undoubtedly appear[23], the field itself will be primarily shaped by the publications that specifically include the interface between science and gastronomy in the various ways pointed out. Further development of molecular gastronomy by food scientists would therefore greatly benefit from having mechanisms to provide financial support and to have specific journals to publish the findings of this research. Otherwise, progress in this area will be limited to those scientists who are passionate about molecular gastronomy and are willing to dedicate their time, energy, and resources to fund this research, to those chefs who are able to set up there own experimental cuisine laboratories, and to those food companies that have in-house chefs to work on particular food products. The dissemination of the results of this research will then be highly restricted to a small number of scientists.

The combination of science and gastronomy will enable educational developments on all levels, from primary education to academia. The combination will be inspiring and will add value to the current educational programs, perhaps even increasing the interest of students for the exact sciences and/or increasing the public interest in health-related food issues in general.

At present, the food industry is largely focusing its research efforts on the development and economic production of foods that promote human health and wellness, e.g., foods with lower salt levels, lower sugar levels, high protein contents, or foods that are fortified with bioactive components, such as calcium, phytosterols, and ω-3 fatty acids. Nevertheless, these foods must also be acceptable and desirable to the food consumer; that is, they should have good appearance, texture, and flavor. A better scientific understanding of what precisely makes a food look and taste delicious may help in the mass production of high-quality, safe, healthy, and nutritious foods.

It is hoped that this article stimulates thought for identifying opportunities that bring together chefs and scientists for the benefit of education, research, and society as a whole.

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