Food Biophysics
DOI 10.1007/s11483-008-9078-3

SPECIAL ISSUE ARTICLE

From the Chef's Mind to the Dish: How Scientific Approaches Facilitate the Creative Process

Juan-Carlos Arboleya · Idoia Olabarrieta · Andoni Luis-Aduriz · Daniel Lasa · Javier Vergara · Esther Sanmartín · Leire Iturriaga · Antonio Duch · Iñigo Martínez de Marañón

Received: 30 November 2007 / Accepted: 29 February 2008

Abstract This work describes a practical way to optimize the high level of the chef creativity to produce rational approaches to food design. It is particularly focused on the preparation of two dishes: *bubbly juice* and *false skin.* For the first dish, three samples were prepared with egg white protein (EWP) and xanthan gum at pH 4.6 and pH 7.0. At pH 4.6 (isoelectric point), there were substantial differences of the interfacial dilational modulus of EWP when xanthan gum was added. At 1 mg/ml xanthan, the system showed a very strong interface (high viscoelasticity) compared to the other samples. Measuring half drainage time revealed which samples were the most stable. The properties discussed were related to stability. For the false skin dish, edible films were made by gelatin extracted from cod skins (A solution) and a mixture of cod skin gelatin and commercial gelatin (AG solution). The results showed that tensile strength (TS) of gelatin films increases almost by 25%, elongation at break (EAB) by 14%, and the Young modulus (E) by almost 100% when increasing protein concentration. To confirm water plasticizer effect, the results were compared to a gelatin film made with 30% glycerol (plasticizer). Water content affects to a great extent the mechanical properties of the films. Finally, images of the dishes are presented in order to have a full view of the purpose and the results obtained.

Keywords Molecular gastronomy · Egg white protein · Cod protein · Foam stability · Rheological properties · Edible film

Introduction

Nouvelle Cuisine represents a style of cooking that breaks down food and flavor and puts them back together again in surprising new forms, with a focus on temperature, texture, and physical structure. Top level cooks are continuously looking for innovation to make delicious and stimulating dishes where generation of new ideas is always needed. For instance, new textures or texture combinations add excitement and generate interest, and thus become a powerful tool for creating new food opportunities. Chefs from *nouvelle cuisine* are highly competent at producing novel food in an empirical way. However, combining science and cooking opens a spectacular and interesting way to make high quality and healthy food for consumers. Among the different definitions about the role of science in the framework of cooking (molecular gastronomy, experimental cuisine, culinology, science-based cooking…), they show common issues about how these interactions must be: (1) science of cooking must be hypothesis-driven, (2) the artistic component of cooking may be helped by scientific approach, and (3) the social component must be taken into account. Regarding to cooking concerns only, some of the best chefs in the world (Adriá, Blumenthal…) have recently stated that scientific understanding must be

---

This research has been supported by the Department of Agriculture and Fisheries from the Basque Government.

This work was presented at the conference *Delivery of Functionality in Complex Food Systems*, Amherst, USA, October, 2007.

J.-C. Arboleya (✉) · I. Olabarrieta · E. Sanmartín · L. Iturriaga · A. Duch · I. Martínez de Marañón
Azti-Tecnalia Food Research Institute,
Txatxarramendi ugartea z/g,
48395 Sukarrieta, Bizkaia, Spain
e-mail: jarboleya@suk.azti.es

A. Luis-Aduriz · D. Lasa · J. Vergara
Mugaritz Restaurant,
Otzazulueta baserria. Aldura aldea 20 zk.,
Errenteria 20100 Gipuzkoa, Spain

another tool for chefs.[1] This will permit to see the science behind the creation of dishes as specific "case studies". These case studies can then be developed in all technical detail by using scientific method. The work described in this paper is particularly focused on two "*case studies*" for the preparation of two dishes: *bubbly juice* and *false skin* by using scientific knowledge about foams and edible film formation.

Protein–polysaccharide mixtures are widely used by cooks as they play an essential role in the microstructure of many foodstuffs. Egg white proteins (EWP), for instance, are optimal ingredients for foam formation. By controlling the rheology of the aqueous phase, food polysaccharides, like xanthan, reduce the thinning rate of aqueous films between bubbles and hence increase the stability of the foam.[2] Formation of protein–polysaccharide complexes is sometimes related to an enhancement in functionality.[3,4]

Gelatin has several functions for foods[5] and it is widely used by cooks. It is one of the most versatile and utilized gelling agents in food application due to its special texture and the "melt-in-mouth" perception.[6] Gelatin films and coatings can enhance the elasticity, consistency, and stability of food products,[7] retaining their juiciness and flavors by the reduction of moisture loss and enhancing their color, texture, nutritional value, and appearance. Importantly, fish skins could be used as a gelatin source, thus giving value to fish wastes and developing value-added products.

Our approach has been always conducted from cooking to scientific vision, where knowledge of science is needed to avoid trial-and-error attempts from cooks. This work shows a practical way that optimizes the high level of chef's creativity to produce rational approaches to food design: from the initial chef's idea, followed by the development of a scientific method, the consequent knowledge transfer, and the final dish presentation. From this experience, we finally state some important facts related to the interaction between science and cooking as key elements for a successful relationship between scientists and cooks.

Materials and Methods

Spray dried egg white protein (82% protein, dry basis) was supplied by Comercial Artesana Sosa, S.L. (Catalunya, Spain) and xanthan gum was provided by Apasa (Gipuzkoa, Spain). All samples were prepared in 0.1 M sodium citrate-phosphate buffer at pH 4.6 and 7.

Interfacial Measurements

Surface tensions at the air–water interface of solutions of protein at a constant concentration (10 mg/ml) and xanthan gum (0, 1, and 4 mg/ml) were measured by using an FTA200 pulsating drop tensiometer (First Ten Ångstroms, USA). The capillary drop was formed within an environmental chamber at room temperature, in which standing water increased the relative humidity to minimize drying effects. When required, changes in γ (surface tension) were monitored with a 1-s resolution. Sinusoidal oscillations of the drops' areas were input by a volume amplitude and the resulting change in γ was used to determine the dilatational modulus. Frequency applied was 0.1 Hz. Strain amplitude was within the linear viscoelastic regime for all samples[16] and corresponded to a relative interfacial area change of ≈3.5%. All measurements were made at room temperature (≈20°C).

Foam Rheological Measurements

These were performed at room temperature (≈20°C) by using an AR 2000 rheometer (TA Instruments, UK). A stainless steel (20 mm diameter) plate with a cross-hatched surface was used as the upper plate with a final gap of 2,000 μm. Steady state flow experiments were performed by using a shear rate ramp on foams from 0.00083 to 0.8 s^{-1}. Oscillatory stress sweep was carried out in the range of 0.008–100 Pa at 1.0 Hz frequency.

Foaming Device

Determinations were made by adding 15 ml of protein solution in a transparent glass tube (3 cm diameter, 30 cm height) marked with volume lines for reading the height of the foam. Presaturated nitrogen gas at constant pressure (gas pressure=1.5 atm) was forced through a gas jet inserted at the bottom of the glass tube (orifice diameter, 229 μm) until the foam reached a maximum level. Time required for the foam to reach the maximum level of the column (20 cm height) was constant with all the samples ($t_0 \approx 10$ s). Evolution of the foam was then recorded for 30 min. Two parameters were determined from the recorded data to characterize foaming properties: $V_{\max}$, maximum liquid incorporated in the foam and $t_{1/2}$, the half drainage time of the foam.

Fish Skin Gelatin Extraction and Edible Film Formation

Fish gelatin was extracted from 1 kg desalted cleaned cod skins in 1.5 l water for 2 h at a temperature of 80°C. The broth thereafter was filtered and heated at a temperature below the boiling point with gentle stirring, until its volume was reduced to by half (A solution). Protein content was determined by both Lowry[8] and Kjeldahl methods. Lowry's method was performed in microplates, using a plate reader (Sunrise, Tecan Austria) with bovine serum albumin (BSA, Sigma-Aldrich, USA) as standard. A conversion factor of 5.4 was used for calculating the protein content from the Kjeldahl method.[9]

Commercial gelatin was added to the cod skin gelatin extracts to increase protein concentration but keeping the handle ability of the films. A more concentrated cod skin gelatin was too viscous to prepare edible films by a casting method. A second solution (AG) was then prepared by adding 2 g of commercial gelatin (Gelita, Deutschland GmbH) to 150 ml of A solution. Edible films were prepared by casting method pouring 10 g of each solution into Petri dishes. In both cases, the filmogenic solutions were dried for 2 days at 25°C in an oven with air renewal and circulation (Memmert, Germany). The resulting films were conditioned in desiccators with saturated solutions of $Mg(NO_3)_2$ 6 H_2O for 50% RH and with distilled water for 95% RH and in silica gel for 0% RH for at least 48 h before testing.

Mechanical Properties

Tensile strength (TS), elongation at break (EAB) and Young modulus (*E*) of cod skin gelatin films were determined by tensile test using a TA.TX2i texturometer (Stable Micro Systems, UK) according to the ASTM Standard Method D882–01.[10] The samples were cut into rectangles of 15 mm width and 60 mm length. The samples were mounted between the grips with initial separation of 40 mm and then pulled apart at cross-head speed of 100 mm/min. The tensile strength was defined as the maximum stress in the nominal stress–strain curve. Samples were conditioned at constant relative humidity (RH) before measuring. The measurement was performed immediately after a sample was taken out from the desiccator. Measurements for each type of film were repeated at least ten times, from which an average was obtained.

Results and Discussion

Bubbly Juice

The original idea from the chef was to try to achieve the following design for a dish: "Trap the food within a bubble, so trap the aroma which may be either from the food itself or smoke. That will be a sudden explosion of senses for the people". From this initial idea, the aim was to create a hemispheric bubble by making a protein solution to lower the interfacial tension which promotes bubble formation, create a viscoelastic interface to stabilize the foam against coalescence, and increase bulk viscosity to slow down drainage.[11]

Three samples were prepared by 10 mg/ml EWP (constant concentration) and 0, 1, and 4 mg/ml of xanthan gum. Final solutions were adjusted to pH 4.6 (EWP isoelectric point) and pH 7. Our research was therefore focused to study how xanthan concentration and pH affects the surface properties of a EWP solution. Dynamic interfacial tension showed that isolated EWP adsorbed more quickly at pH 7 than at pH 4.6 (Figure 1a). Adding 1 mg/ml xanthan seemed to slow down protein adsorption, especially at pH 4.6, giving higher interfacial tension values at both pHs (Figure 1b). At 4 mg/ml, it did not seem to affect protein adsorption as interfacial tension values were similar than the isolated EWP (Figure 1c). Surface tension values did not really exhibit great differences among the samples for our purpose. In all the cases, surface dilational modulus (*E*′) started with low values and grew to a maximum, forming the film, then settles back a bit after the film was formed (Figure 2). Isolated EWP seemed to have similar surface rheological properties at both pHs

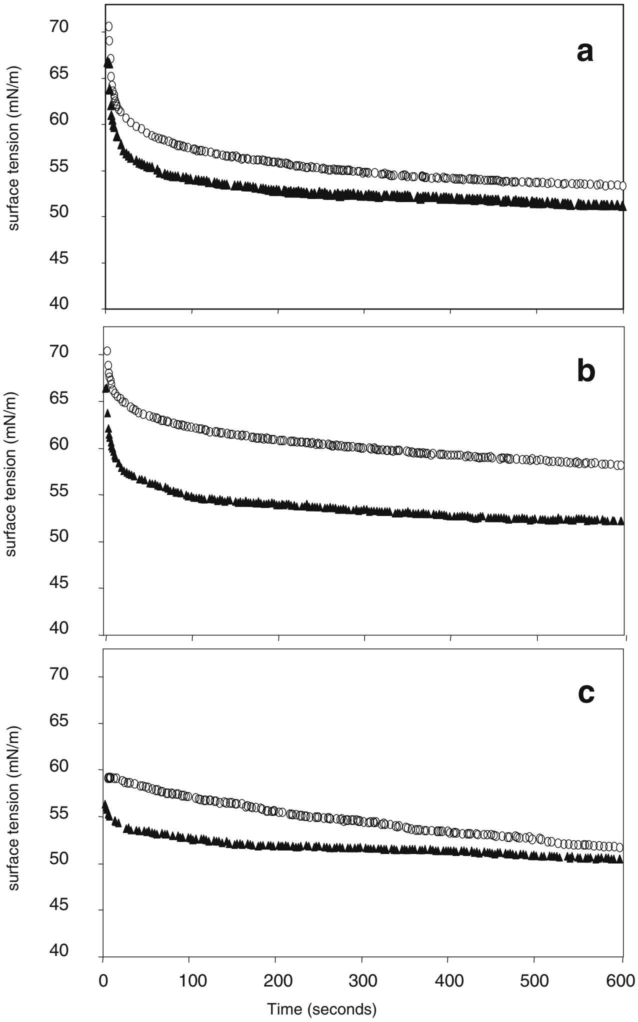


Fig. 1 Dynamic surface tension measurements of 10 mg/ml protein solution; **a** no xanthan; **b** 1 mg/ml xanthan; **c** 4 mg/ml xanthan at pH 4.6 (*empty circle*) and pH 7 (*filled triangle*)

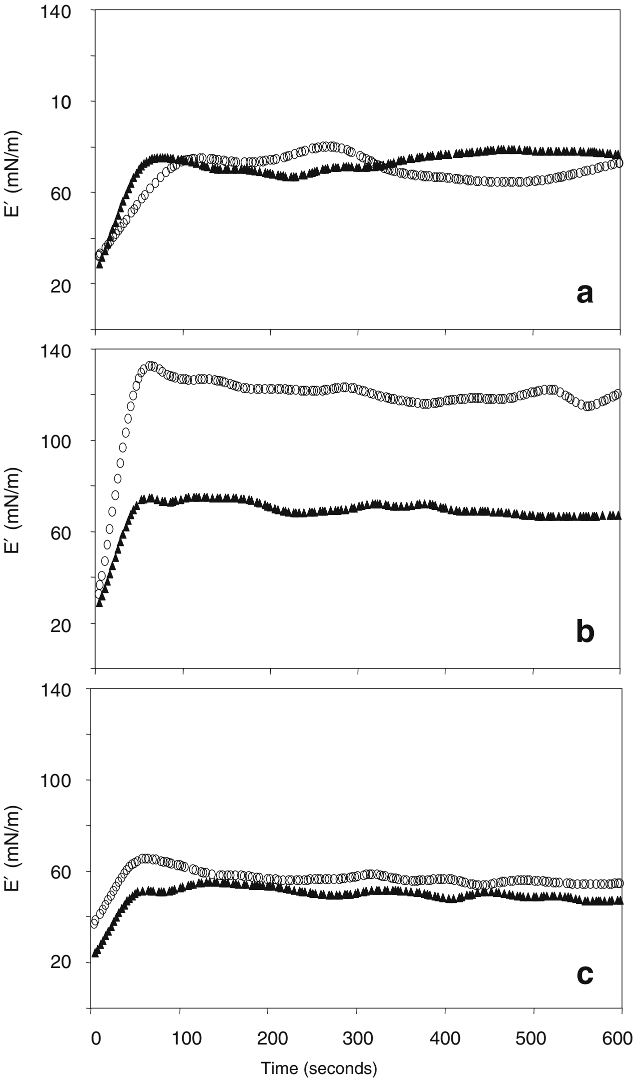


Fig. 2 Interfacial dilational modulus measurements of 10 mg/ml protein solution; **a** no xanthan; **b** 1 mg/ml xanthan; **c** 4 mg/ml xanthan at pH 4.6 (*empty circle*) and pH 7 (*filled triangle*)

(Figure 2a). At 1 mg/ml xanthan, interfacial elasticity increased considerably at pH 4.6 whereas at pH 7, rheological behavior looked similar to isolated EWP (Figure 2b). However, adding 4 mg/ml xanthan slightly decreased dilational modulus at both pHs (Figure 2c). At this concentration, protein diffusion to the interface appears rather difficult due to a high viscosity in the bulk.

At pH 4.6 (isoelectric point), there were substantial differences for the interfacial behavior of EWP when xanthan gum is added. At 1 mg/ml xanthan showed a very strong interface (high viscoelasticity) and slower adsorption dynamics, likely caused by bulk viscosity limitation.[12] Anchorage of the polysaccharide at the interfacial film may also occur by an interfacial complex formation of the polysaccharide with the adsorbed protein, depending on the chemical structure of the polysaccharide and on the pH.[13] Above the isoelectric point of the protein, thermodynamic incompatibility between the protein and polysaccharide generally occurs because of the repulsive electrostatic interactions and different affinities towards the solvent.[14] A slight decrease of surface tension observed at high concentration of xanthan (4 mg/ml) may be taken as an evidence of a “concentrating effect” caused by the limited thermodynamic compatibility between the biopolymer and the protein.

Based on the described data, subsequent experiments were focused on samples that appeared to have the most viscoelastic interface (EWP solutions at 1 mg/ml xanthan). The solution at pH 4.6 showed much higher values in shear stress than the one at pH 7 (Figure 3a), suggesting that at pH 4.6, there is a substantial increase in the firmness of the foam. The onset of a more viscoelastic behavior at pH 4.6 was also developed (Figure 3b), so a much more elastic foam could withstand more mechanical forces than the control foam. Foaming experiments showed that at early stages, solutions at pH 7 (lower surface tension) seemed to initially keep more liquid in the foam (Figure 4a). However, foam stability results revealed a slower drainage rate in solutions at pH 4.6 (Figure 4b). Interfacial rheology parameters of proteins are important for foam stability. By forming an elastic interface, they can retard liquid drainage from foams and thus stability. The more elastic interface gave more stable foams at pH 4.6 although bulk viscosity played also an important role for drainage stability.[15] EWP

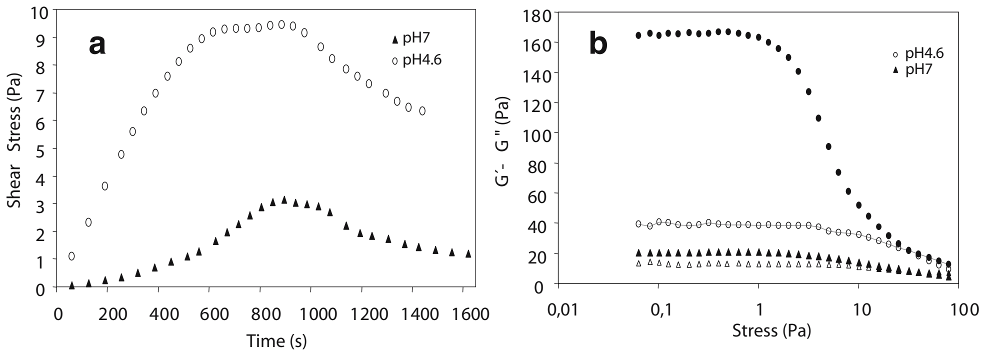
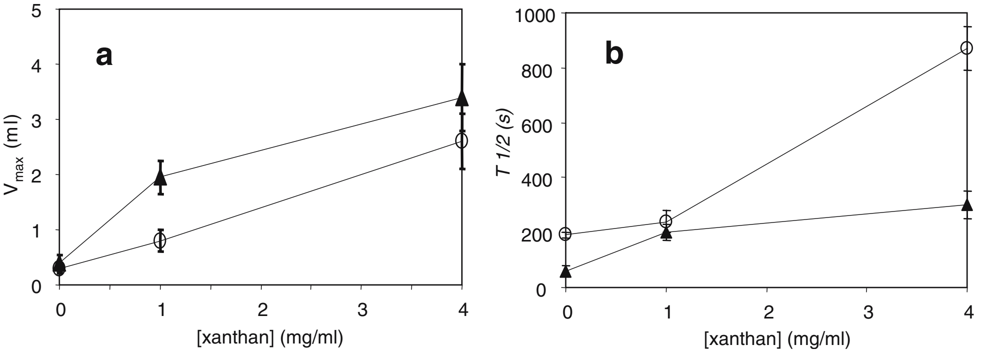


Fig. 3 Rheological properties of foamed solutions (10 mg/ml protein solution and 1 mg/ml xanthan); **a** Steady state flow experiments. Shear ramp on foams from 0.00083 to 3 s^{-1}; **b** oscillatory stress sweep experiments. 0.008–100 Pa; 1 Hz frequency; pH 4.6 (*empty circle*) and pH 7 (*filled triangle*)

Fig. 4 Foaming experiments of 10 mg/ml protein solution with no xanthan, 1 mg/ml xanthan and 4 mg/ml xanthan at pH 4.6 (*empty circle*) and pH 7 (*filled triangle*); **a**) V_{max}, maximum liquid incorporated in the foam and **b**) $t_{1/2}$, the half drainage time of the foam



solutions at 4 mg/ml xanthan had lower interfacial elasticity but much greater viscosity. From the stability results, it looks like viscosity is the key factor. An increase in yield stress with increasing foam stability is logical, as more stable foams should have higher air phase fraction of the foam and smaller bubbles.[16]

These results were then communicated to the chef by transferring them into recipes: an aqueous solution should be made by adding 10 mg/ml EWP and 1 mg/ml xanthan gum at: (1) pH 4.6. This pH could be reached by adding a beet root solution. This recipe gives more foam stability and produces smaller and more compact foams (Figure 5); (2) pH 7. This pH could be reached by adding cocoa powder to the solution. It makes less stable foam and produces bigger bubbles (Figure 6).

False Skin

The original idea from the chef was to achieve the following design for a dish: “Betray the sense of sight and give a different initial taste to the white fish by covering it with a false skin”. The scientific approach was to create films made with gelatin extracted from cod skins. This broth was initially used to replace butter in sauces and it showed excellent gelling properties (data not shown). After reducing its original volume to half, it was used for the casting of edible films. Covering the white fish with the film would provide a “more tasty” effect in white fish. This part of the work is a first approach in the definition of the optimal physical parameters for developing easy handle films which may help cooks to create innovative fish dishes.

The extracted solution (A solution) had a protein concentration of 10–12%. This result is a bit lower than the ones reported by other authors[17–19] but this could be due to the different species of fish used and the extraction method.

In order to enhance the taste and nutritional properties of food and to improve mechanical properties of the developed films/coatings, as desired by cooks, protein concentration was increased by adding 2 g of commercial gelatin to 150 ml of A solution. The results revealed (Table 1) that the TS of gelatin films increases by almost 25%, the EAB by approximately 14% and the Young modulus by almost 100% when increasing protein concentration. This tendency is in agreement with other reports.[20]

Fig. 5 Version of bubbly juice at pH 4.6; sun ripened berry fruits lightly covered in virgin olive oil and lime. Cold beet root bubbles. Photograph from Jose Luis Lopez de Zubiria

Fig. 6 Version of bubbly juice at pH 7; Vanity; mouth watering chocolate cake, garnished with chilled cream from real milk, complimented with traces of gold and smoky bubbles of cocoa. Photograph from Jose Luis Lopez de Zubiria

Table 1 Mechanical properties and thickness of cod skin gelatin film type A and film type AG

Film type	Tensile strength (TS) MPa	Elongation at break (EAB) %	Young modulus (*E*) MPa	Thickness µm
A	42.42±3.03	4.98±0.2	599±40	90±26
AG	53.71±2.43	5.69±0.5	1,194±237	112±14

As expected, films made from more concentrated solution showed more resistance, stiffness, and toughness.

The extracted gelatin solution had good film forming properties but they were too brittle in dry conditions. Although adding plasticizer would improve the film's mechanical properties, no plasticizer was included to avoid undesirable taste and texture changes in the final fish dish. This did not present any problem for the preparation of the dish because water appears to be an effective plasticizer on protein films.[21] Thus, to see the influence of the water on the mechanical properties, the films were tensile tested at 95%, 50%, and 0% relative humidity. To confirm the plasticizing effect of water, the results were compared to a gelatin film made with 30% glycerol (plasticizer). The results summarized in Table 2 shows that water content substantially affects the mechanical properties of the films. Due to the fact that relative humidity is also a function of temperature, it is obvious that it will be imperative to control the environmental conditions to have the desirable material properties.

These results were then communicated to the chef by (1) adapting the mentioned protein extraction and (2) transferring the casting method into the kitchen. The formed film was then painted by using edible colorants to provide a similar resemblance to fish skin (Figure 7) and it was then placed on top of a piece of monkfish (Figure 8).

Conclusions

From this study, we conclude that cooking and science are well placed to work in harmony for both the development and realization of innovative and healthier dishes. The effect of xanthan gum and pH in our solution clearly played an important and integral role for the coalescence stability of protein-stabilized air bubbles. These parameters were controlled to design foams with different properties. Edible gelatin films can be properly prepared with a simple methodology and their properties can be improved, simply by controlling protein concentration and environmental conditions, such as relative humidity and temperature.

Independently of our scientific conclusions, it is perhaps pertinent to point out some important facts related to the interaction between science and cooking. “Science is the best friend of creativity” (Harold McGee) and it can “give new tools and open new paths” (Davide Cassi). Andoni Luis Aduriz (Mugaritz Restaurant) reports that “science and technology is a magnifying glass for the cooks…this may create great benefit for the good cook, but it will be a disaster for the bad cook”. It seems clear that the synergy between science and cooking is dependent upon sensible integration of the two disciplines. There is however a thin line which scientists should not cross. The aim for scientists should not be simply to reduce cooking to science by means of long and impenetrable equations. Equally, it is not necessary to pursue novelty for its own sake—scientific solutions need only be sought for practical problems.

While scientists can give great benefit to cooks, the relationship is also reciprocal—scientists can gain from the knowledge, skills, and innovation of cooks. They are continuously contributing with fresh and new ideas, some of which are incredibly interesting and motivating from a scientific and industrial point of view. In addition, they are well placed to help communicate science to society, and area where there is an obvious but reducible disconnection. By capitalizing upon the potential for the general public to listen to chefs and cooks, a bridge may be developed to educate people about a better and healthier way of eating based on scientific criteria.

Table 2 Mechanical properties of gelatin films as affected by relative humidity and glycerol addition on film type AG

Film type	Relative humidity (RH) %	Tensile strength (TS) MPa	Elongation at break (EAB) %
AG film	0	Brittle	Brittle
AG film	50	53.71±2.43	5.69±0.50
AG film	95	0.41±0.102	219±65.78
AG film:glycerol	50	1.50±0.05	146.70±27.37

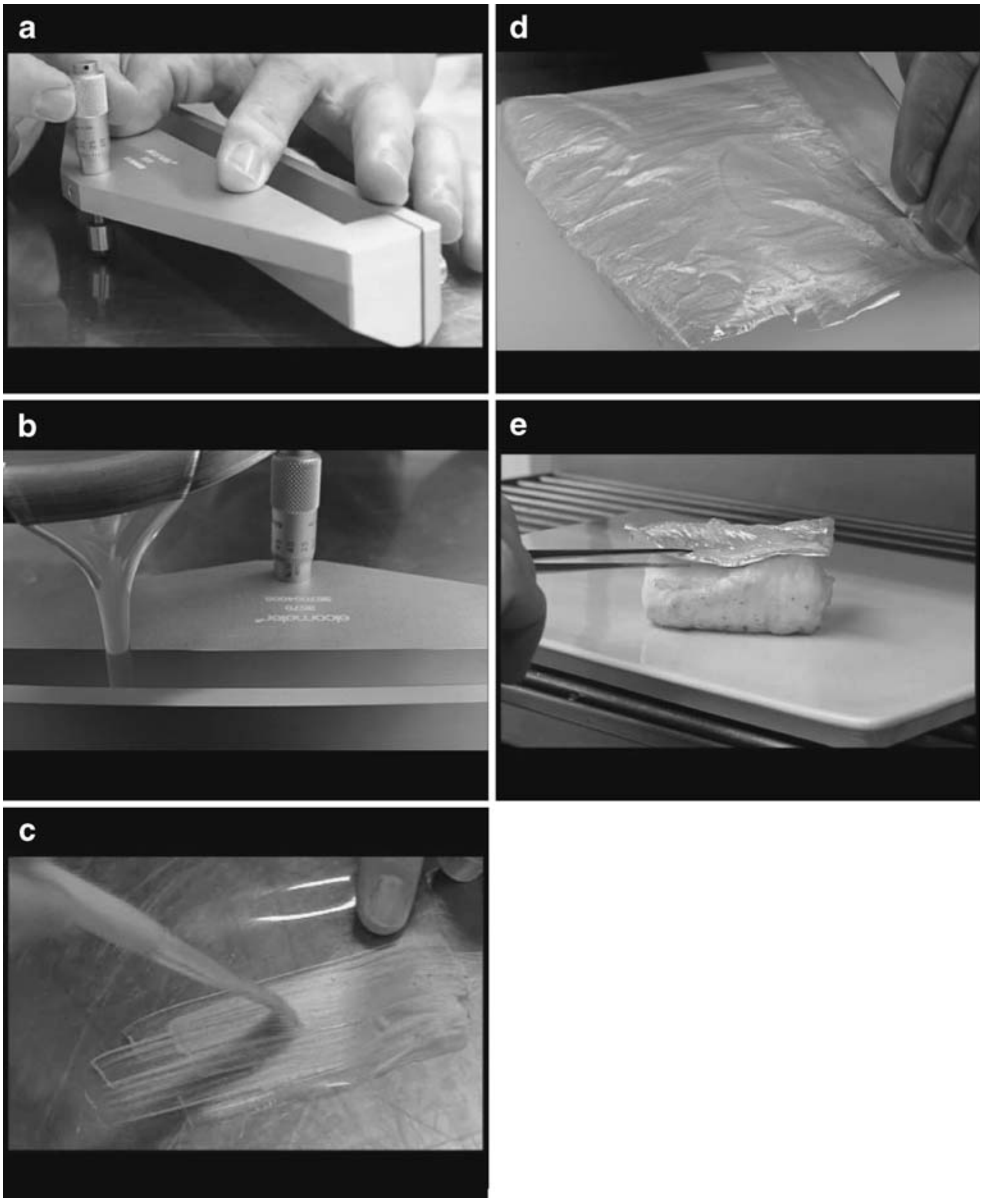


Fig. 7 Making films in the kitchen by a casting method; **a** choosing thickness; **b** spreading of gelatin solution; **c** painting by using edible colorants; **d** cutting the film; **e** settling the film on top of a piece of monkfish

There is, however, a real concern within the culinary community as to whether the term “molecular gastronomy” should be redefined or not. Gastronomy is the study of relationship between culture and food and molecular gastronomy does not really cover these aspects. Furthermore, the public tend to be skeptical with this name as it sounds highly elitist, complicated, and unsafe. If one of the big issues between the interactions of scientific and cooking communities is communication, we believe that this name does not really help to achieve that goal. One step forward would be to consider the modification of the name “molecular gastronomy” into an easier and more representative one. In any case, the most important thing for us is that collaboration between both communities should be encouraged irrespective of whatever name this is to go by.

Fig. 8 Presentation of the final dish: roast monk fish loin “with skin”. Photograph from Jose Luis Lopez de Zubiria

Acknowledgements The authors would like to acknowledge Dr Brent Emerson for his help during the writing of this manuscript.

References

1. F. Adria, H. Blumenthal, T. Keller, H. McGee (2006). *Statement on the "new cookery"*, accessible at http://observer.guardian.co.uk/foodmonthly/story/0,,1968666,00.html
2. E. Dickinson, E. Izgi, Colloids Surf. A Physicochem. Eng. Asp **113**(1–2), 191–201 (1996)
3. J.C. Arboleya, P.J. Wilde, Food Hydrocoll. **19**(3), 485–491 (2005)
4. R. Baeza, C.C. Sanchez, A.M.R. Pilosof, J.M.R. Patino, Food Hydrocoll. **18**(6), 959–966 (2004)
5. Yudi Pranoto, Chong Min Lee, Hyun Jin Park, LWT–Food Sci. Technol **40**(5), 766–774 (2007)
6. Ingvild J. Haug, Kurt I. Draget, Olav Smidsrod, Food Hydrocoll. **18**(2), 203–213 (2004)
7. P. Montero, M.C. Gomez-Guillen, J. Food Sci. **65**(3), 434–438 (2000)
8. O.H. Lowry, H.I. Rosebrough, A.L. Farr, R.I. Randall, J. Biol. Chem. **193**, 265–275 (1951)
9. J.H. Muyonga, C.G.B. Cole, K.G. Duodu, Food Hydrocoll. **18**(4), 581–592 (2004)
10. ASTM. (2001). Standard test method for tensile properties of thin plastic sheeting. Annual book of ASTM standards. Designation D882-01. Philadelphia: ASTM, American Society for Testing Materials
11. P.J. Wilde, Mackie, Verlag Metall Innovation Technologie MIT 59–64 (1999)
12. P.J. Wilde, Curr. Opin. Colloid Interface Sci. **5**(3–4), 176–181 (2000)
13. R. Baeza, C.C. Sanchez, A.M.R. Pilosof, J.M.R. Patino, Food Hydrocoll. **19**(2), 239–248 (2005)
14. V.B. Tolstoguzov, Food Hydrocoll. **4**, 429–468 (1991)
15. D.J. Carp, G.B. Bartholomai, P. Relkin, A.M.R. Pilosof, Colloids Surf. B Biointerfaces **21**(1–3), 163–171 (2001)
16. J.P. Davis, E.A. Foegeding, Colloids Surf. B Biointerfaces **54**(2), 200–210 (2007)
17. Magnus Gudmundsson, Hannes Hafsteinsson, J. Food Sci. **62**(1), 37–39 (1997)
18. Peng Zhou, Joe M. Regenstein, J. Food Sci. **70**(6), c392–c396 (2005)
19. S. Zhang, Y. Wang, J.L. Herring, J.-H. Oh, J. Food Sci. **72**(9), C498–C503 (2007)
20. A. Jongjareonrak, B. Soottawat et al., Food Hydrocoll. **20**(4), 492–501 (2006)
21. Rungsinee Sothornvit, John M. Krochta, J. Food Eng. **50**(3), 149–155 (2001)