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MOLECULAR GASTRONOMY IN SPAIN

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ABSTRACT

Beyond the overwhelming international success of Ferrán Adria, Spain has been one of the countries with a more active implication in Molecular Gastronomy as a scientific discipline, but also in the use of ingredients, technologies and equipment from the scientific and technological universe in the culinary area. Nowadays, this is a well-established discipline in Spain, with a number of research groups covering related topics, several companies commercializing appliances and additives worldwide and renowned international chefs and many restaurants and companies committed to the collaboration with scientists for facing the future of Spanish gastronomy.

KEYWORDS

Molecular gastronomy; Spain; research; technology; education; chefs.

INTRODUCTION

Spain was perhaps the country in which the revolutionary changes in the new way of understanding cooking had been more evident, especially due to astonishing international impact that some Spanish chefs, such as Andoni Luis-Aduriz, Joan Roca, Juan Mari Arzak and particularly, Ferran Adria, had on the global culinary trends during last decade. These chefs set a cooking standard based on the use of non-traditional appliances, techniques and ingredients, at the summit of the haute cuisine worldwide, and as a consequence, the name of Spain rose to the top of the gastronomy universe.

That said, it could be claimed that this was not Molecular Gastronomy. In fact, following the conception of This (2011), the terms used would more properly be called Molecular Cuisine, or Modern Cuisine, or scientifically based cooking. At any rate, there was a clear connection between the objectives of molecular gastronomy as a scientific discipline, and the development of new recipes using new ingredients and technologies similar to the relationship between food science and food engineering. Therefore, the reviewers tried to show the main milestones of this discipline in Spain during the preceding years, including not only scientific topics but also those concerning the culinary world.

Altogether considered, Spain was no doubt a leading country in this area. Not only because of the unquestionable recognition received in this category by Spanish chefs but –Spain also had been recognised as the first country in which additives such as sodium alginate, gellan gum of glycerol monostearate and a handful of others, were massively commercialized for restaurants and foodies. In addition, Spain had been one of the main producers of new professional kitchen appliances based on equipment from research labs such as the Gastrovac ®, the Rotaval ® or

the Roner ® and was one of the few countries in which many of the main researchers involved in these topics had been linked through a collaborative network: “INDAGA: Research, innovation and development applied to gastronomy”.

This review offers an historical perspective on how Molecular Gastronomy as a discipline, and the application of science and technology as a global area, evolved in Spain during the last 15-20 years, and how it will currently face the future.

EARLY WORKS

Cooking may be a tradition, but cooking evolved due to curiosity. In old recipe books, it was not common to find instructions about how to use one ingredient as opposed to another or descriptions about how food changes during cooking. There always had been curious cooks who tried to understand the scientific principles that underlie cooking. In Spain, at the beginning of the Twentieth Century lived a chef who set the basis of the modern cooking: Teodoro Bardají. Bardají was born in Binéfar (Huesca) in 1882 and died in Madrid in 1956. He was a very dedicated and an erudite chef. When he was young, he learnt confectionery and patisserie. Bardají also moved to France and studied French in order to better understand the most important cooking in Europe: French cuisine. He was really a pioneer of the modernist cuisine in Spain. In the first edition of his book “La cocina de Ellas” in 1935, was found a description of the uses of agar-agar for cooking (Bardají, 1935). There were instructions for its use as a thickener and as a gelling agent. Some recipes prepared with this ingredient were also included. It was published more than fifty years before Ferran Adriá prepared his “hot jellies” with agar-agar. In an interview, Teodoro Bardají summarized his point of view about cooking: “Nowadays a chef that is proud to be a chef has even to know the calories of an artichoke; the nutritive value of bread or

lard; the mixtures of ingredients that go well together and those which not. A chef has to be a chemist but not for adulterating foods, but to use ingredients accurately" (Bardají, 1935).

But, in thinking of a Spanish chef who represents the relationship between science and cooking, no doubt Ferran Adriá needs to be mentioned. He joined the elBulli staff in 1984. During those days the recipes at elBulli were versions of classical cooking and nouvelle cuisine dishes, but they did not create their own recipes. At the beginning of 1987, Ferran Adria's point of view about cooking completely changed. He attended a demonstration in Cannes, in which chef Jacques Maximin claimed: "Creativity means not copying". This simple sentence was the cut-off point in Ferran Adrià's cooking: he took the decision to become involved in creativity and try to find his own identity (Pujol, 2009).

During the 90's in several different locations, elBulli`s team established an off-season workshop called "elBulli Taller": a place for developing new ideas, new dishes and new techniques during the closure period (Pujol, 2009). elBulli's creative team started to expand their idea of creativity not only toward mixtures of products or variations on concepts that already existed, but also created new concepts and techniques. The quest for self-identity and curiosity led to an increased use of scientific tools in the kitchen. The technique-concept search gave rise in subsequent years to foams, hot jellies, the frozen savoury world, etc. In 1997, elBulli was awarded three Michelin stars and became one of the most important restaurants in the world (Pujol, 2009).

During these years, the contact with the scientific world was sporadic as far as the link between science and cooking: In the beginning, the use of certain ingredients and techniques were only for the purpose of creating new dishes. At the

beginning of the twenty-first century, elBulli's team decided to find out why these preparations were possible, what physical and chemical processes were involved and how the products acted that made these textures possible. As Ferrán Adriá said: "All this was because of our conviction that awareness of the scientific processes involved in cooking constituted the basis for evolution" (Pujol, 2009). During those days, Ferran Adrià contacted Professor Rosa Oria at the University of Zaragoza as well as Pere Castells and Ingrid Farrè (a chemist and food scientist, respectively). Several years later these three would constitute the basis of the ALICIA foundation.

And, what about scientists? At the University of Zaragoza, Rosa Oria, a Professor of Food Technology, a gourmet, and a member of de Academy of Gastronomy of Aragón, translated the books about science and cooking by Hervé This into Spanish. The first one was "Los Secretos de los Pucheros" (originally, "Les Secrets de la Casserole") (This, 1996). In Spain, at the end of the twentieth century, it was almost impossible to find a book about science and cooking. Books like "On food and cooking" from Harold McGee or Hervé This were absolutely unknown in Spain. However, in 1998, Joaquín Pérez- Conesa, a chemist and also a food lover, wrote a book entitled "Cocinar con una pizca de ciencia" (Cooking with a pinch of science) (Perez-Conesa, 1998). In this book, Perez-Conesa explained Spanish recipes from a scientific point of view (Pérez-Conesa, 1998). Unfortunately, the book did not have a wide diffusion; although it was still considered an important reference for science and cooking in Spain.

During the 90's in Europe, an interest bloomed about science and cooking. Nicholas Kurti, Hervé This and Harold McGee organized workshops about Molecular Gastronomy in Erice (Sicily, Italy). The first one was held in 1992 and each workshop lasted three to four days. The participants were mainly scientists from universities,

those from the food industry, and some professional cooks. Most participants were from France, USA and UK; but, in 1999, Jorge Ruiz, a Spanish scientist, attended to the Erice Workshop. By that time, Jorge Ruiz was a young Assistant Professor at the University of Extremadura who participated in the Erice Workshop by explaining topics about the flavour of Iberian Ham. Curiously, Ferran Adrià, the most influential pioneer of experimental cooking, was never invited to the Erice workshops.

BEGINNING OF 21st CENTURY: 2000-2005

At the beginning of this century, there was a milestone for molecular gastronomy in Spain. Some of the most renowned Spanish chefs were involved in the exploration of scientific approaches to cooking. Thus, in parallel to the launch of elBulli Taller by Ferran Adria, Joan Roca (El Celler de Can Roca, Girona) and Narcís Caner (La Fonda Caner, Girona) developed the Roner© (ICC, Barcelona, Spain) This thermostated bath, adapted from laboratory use, allowed cooking using a bain marie but with a constant, controlled and identical temperature throughout the entire volume of water. It could also control low temperature cooking, between room temperature and 100° C. As a consequence of the rapid, widespread employment of sous-vide cooking using this type of baths, Joan Roca and Salvador Brugues edited the book “La cocina al vacío” (“Vacuum cooking”) in 2003 (Roca & Brugues, 2003). Other technical innovations at “El Celler de Can Roca” were the development of a “Dessert menu of aromas” (2002), the use of a culinary rotary evaporator (Rotaval ®, 2004) for obtaining distillates as flavor extracts, and the development in 2005 of a smoke pipe for smoking products directly on the plate.

In order to combine the rigorous work of applied physics and chemistry with

the principles and style of this new cuisine type, many chefs created partnerships with the University to obtain the scientific knowledge that enabled them to create new recipes. Since 2000, the Polytechnic University of Valencia was involved in cooking innovation and the link between cuisine and science. In 2003, researchers from this University developed the Gastrovac® (Martínez- Monzó, Andrés, Torres, San Juán, & García-Segovia, 2004) (Figure 1) in a shared research project with Javier Andrés (La Sucursal restaurant in Valencia) and Sergio Torres (El Rodat restaurant, Alicante). At a first sight, this appliance was similar to a pressure cooker but it had a vacuum pump that generated an oxygen-free low-pressure atmosphere inside. This allowed foods to be cooked at temperatures lower than usual, protecting their textures, nutrients and color (García, Andrés, Martínez & Torres, 2005). These authors called this cooking procedure “cooked-vide”. In this cooking procedure, the pressure under which the food was cooked was reduced; whereas, in sous-vide cooking, once the plastic pouch was sealed, the pressure was atmospheric. Moreover, with this equipment it was possible to perform vacuum-frying, a cooking technique which (1) reduced the oil content in the fried product, (2) preserved natural colour and flavours (better than with conventional deep fat frying), and (3) reduced the adverse effects on oil (Andrés-Bello, García-Segovia & Martínez-Monzo, 2010). This appliance also allowed vacuum impregnation of fruit and vegetables (García-Segovia, Andrés-Bello & Martínez-Monzo, 2011). Such a technique was routinely used in the food industry, but was not known as a culinary tool.

In these first years of the Twenty-first century, at the University of Extremadura, Jorge Ruiz started to get more and more involved in research activities about cooking. Ruiz started to collaborate with Toño Perez (Restaurante Atrio, Caceres, Spain) and participated as a speaker at the “Journée Française de la

Gastronomie Moléculaire" (2001) and the "First Meeting of the Club of Molecular Gastronomy" (2005), both in Paris. At the "1st International Congress on Food Safety" (Murcia, 2005), he gave a speech entitled "Molecular Gastronomy". Also, by that time (2005), he had obtained funding from the regional government to launch a project entitled "Study and improvement of culinary processes in haute cuisine", in which the culinary purpose of techniques such as vacuum distillation, vacuum cooking and ingredients such as transglutaminase, were studied.

The ALCOTEC project ("Haute cuisine and technology") was launched between the University of Zaragoza and the Government of Aragon (a region in Spain) in 2004. The goal of this research team was to develop new culinary tools based on scientific and technological knowledge, and to spread the use of such tools to the chefs through courses and collaborations. As an example, this team was awarded in 2005 with the Technological Innovation Award in Madrid Fusion Congress for the use of a microfiltration membrane system to produce an innovative clarified and transparent "gazpacho" (a Spanish cold vegetable cream soup).

Similarly, in 2005, the restaurant Mugaritz, run by Andoni Luis Aduriz, signed a framework agreement with AZTI-Tecnalia (Technological Research and Innovation Centre in Basque Country) aimed at adapting new concepts and ideas to transform them into new foods for the consumer. Aduriz also collaborated with the Professor of Anatomical Pathology, Raimundo Sánchez del Moral, in a shared project about the quality of duck foie from a culinary and histological point of view (García del Moral, 2004). He also cooperated with Dani Garcia (Calima restaurant, Malaga), popularising the culinary use of liquid nitrogen for applications beyond to its simple use for producing sorbets (O'Valle, García del Moral & García del Moral, 2004) as well as organising a workshop on Molecular Gastronomy in Granada in 2004.

During this first five years of the 21st century, some of the most important gastronomy congresses were launched, but above of all, Madrid Fusion (the first edition took place in 2003) became a platform in which the last cooking techniques and appliances were shown annually, with worldwide impact. This congress was committed to spreading the collaboration between science and cooking, and the participation of Herve This (2003 and 2004), researchers from the ALCOTEC project previously cited (2006) or Jorge Ruiz from the University of Extremadura (2007) as speakers was not unusual.

LAST YEARS (2006-2012)

This period could be considered as the consolidation of the relation between Science and Cooking all over Spain in any aspect whatsoever. Apart from the most innovative chefs, a significant number of other chefs started to see science as an important and useful tool for their kitchens and real interaction became even stronger than in previous years. A good example of this evidence was the foundation of the Science and Cooking Networking INDAGA, which was about innovation, research and development as applied to Gastronomy. This network was funded in 2006 and was aimed at coordinating the R&D activities carried out at different Spanish universities, foundations, catering schools and research institutes in order to gain visibility for industry and society. This interesting initiative allowed both new (i.e. ALICIA foundation) and active working teams to join and work together to respond to all challenges and needs in the food field, especially those related to gastronomy and nutrition. In fact, Ferrán Adriá, a famous chef, and Valentí Fuster, a famous scientist, led this project. One of their main goals was to unify scientific accuracy with a more comprehensible language, which would make it accessible to the culinary

world. This idea was published as “Léxico Gastronómico-Científico” in 2006 (Fundación Alicia, elBulli Taller, 2006).

Since its foundation, INDAGA pursued very clear objectives, which agreed with the steps that Spain had made in past years; among these were the study and transfer of different techniques and knowledge from the scientific field to the cooking sector. This objective was made possible by creating a real connection and collaboration between research teams, companies, chefs and catering schools. Dissemination was another key factor for the success of this interaction and, of course, education at different levels by which to integrate and consolidate science at the gastronomic level. All these achievements eventually made it possible to contact other international organizations.

From this routing sheet, there were numerous activities done for INDAGA, thereby achieving all the network’s proposed objectives. Chef Sergio Laguarda, from the Catering School of Alcalá de Henares (Madrid), which was closely related to IMIDRA (Madrid Research Institute of Rural, Farming and Food Development), became proactive in his drive to draw the real interests of gastronomic professionals into the scientific aspects. After several meetings between scientists and chefs at the ALICIA foundation, a scientific and gastronomic vocabulary was established between these two disparate fields and proclaimed at the 2007 Technical University of Valencia’s annual symposium of Science and Cooking on both a national and international level. Through the years, the network endorsed multiple courses, conferences and workshops such as: “Vacuum cooking of meat at moderate to low temperatures: physico-chemical changes and formation of volatile flavor compounds” by Dr. Jorge Ruiz; the workshop “Analytical and chemical aspects related to thermally processed foods” (COST 927 Action “Thermally processed foods: possible

health implications") held in Aveiro, Portugal (2009); Dr Dolores Garrido, University of Murcia's, Science and Cooking symposium lecture (organized by the European Centre of Innovation and Enterprises [CEEIM]); *"Industrial approach to chef's creativity"* the 15th World Congress of Food Science and Technology, (IUFoST, Cape Town, 2010) invited lecture by Dr Juan-Carlos Arboleya, Azti-Tecnalia Food Research Institute; and the *"Science and Cooking: a path through history"* invited lecture by Dr Antonio Vercet, University of Zaragoza, presented at CSIC-IATA (Valencia).

Dissemination of remarkable work being done incorporating both science and cooking was being spread at both professional and public levels. A good example was a book published by Claudi Mans concerning the science in both traditional and modern cooking techniques (Mans, 2010) as well as the many publications in different scientific journals; which showed real interactions between scientific work and new culinary concepts. The problem with these published scientific papers was that chefs did not have a venue for showing off their creations in an assertive scientific and serious manner. That was the reason for the creation of the International Journal of Gastronomy and Food Science by the Azti Food Research Institute and Mugaritz Restaurant. This journal filled the gap in the expanding fields of Gastronomy and Food Science by adopting a scientific approach.

Paralleling this application of scientific and technological knowledge through renowned chefs, and paired with the scientific research and development efforts and cooking topics brought about by numerous research groups, the academic education of a professional chef turned toward becoming more cognizant of scientific and technological knowledge. This knowledge was reflected in 2006 by courses being taught to chef instructors about new cooking tools and techniques by Prof. Jorge

Ruiz (University of Extremadura) and by Raúl Ruiz (AlcoTec member), in the public cooking school of Orellana la Vieja (Badajoz, Spain). This new academic curricula for the different official culinary programs significantly expanded the scientific content of the professional chef's training.

Another important initiative in teaching was the creation of a new bachelor degree in gastronomic sciences at the Basque Culinary Centre. The Basque Culinary Centre Foundation was created by Mondragon Unibertsitatea in 2009 for Basque chefs and other public culinary institutions. The goal of the Basque Culinary Centre was to guarantee the continuity of this innovative cuisine for the future. This goal also implied that there would be a generation of high-level knowledge and training of qualified professionals; thereby promoting research and knowledge transfer among haute cuisine professionals and business sectors relating directly and indirectly to gastronomy.

CURRENT RESEARCH LINES

In Spain, there were several groups conducting projects on topics including the Molecular Gastronomy area that were either funded by public agencies or supported by various companies. For example, the group from the University of Extremadura, led by Prof. Ruiz, had extensively studied the effects of time and temperature on different parameters of sous-vide cooked meats. Through their research, they had verification of the effect of vacuum packaging on the final physical and chemical characteristics of pork cooked over an extended time and at different temperatures (Sánchez del Pulgar, Gázquez & Ruiz, 2012). They also contributed to the understanding of the effect of time and temperature combinations on the generation of volatile compounds in sous-vide cooked pork through different methods; including

Maillard reactions and lipid oxidation (Ruiz, Roldan & Sánchez del Pulgar, 2013). The time/temperature effects on the development of texture and colour features of sous vide cooked pork (Sánchez del Pulgar et al., 2012) and lamb (Roldán et al., 2013), also had been considered. In the latter study, by using Cryo-SEM images, the collagen degradation over six hours cooking time at 60ºC in sous-vide cooked lamb was noted (Figure 2). Oxidative changes underwent by lipids and proteins in sous vide cooked lamb have been also thoroughly studied (Roldan, Antequera, Armenteros & Ruiz, 2014). In addition, this research group had devoted a great effort in the study of the microstructure of different crispy foods and its relationship to the instrumental and sensory textural characteristics of these foods, including dried and freeze-dried foams, microwaved pork rinds or fried battered calamari (Barata, 2012). For example, Barata showed the differences in texture of yogurt-based foams (made with yogurt and different hydrocolloids; siphoned after cooling for one day) that were either dehydrated by drying with hot air or by freeze-drying. Despite to the fact that both types of dehydrated foams had exactly the same composition and were dehydrated to a similar extent, those subjected to freeze-drying showed a much softer texture, reflected in the number of fracture events when analysing the force versus time curve after compression in a Kramer Shear Cell (Figure 3).

Ruiz's group also described the effects of transglutaminase on the texture and thermal stability of gelatine gels and foams (Ruíz & Calvaro, 2007 a, b), the use of different culinary strategies for restructuration, including the use of sodium alginate, microbial transglutaminase or fibrinogen/prothrombin (Ruíz & Calvarro, 2012) and the elaboration of rock rose flavour extracts for culinary purposes by distillation in a rotary evaporator (Ruíz, Muriel, & Rodríguez, 2007).

Changes in the consumer demands, the need to adapt to technological

advances, and the economic pressure had important consequences for the catering industry. Therefore, the University of Murcia's Food Science and Technology research group studied and developed the method of sous-vide cooking of fish and meats from a catering perspective. Sous vide cooking perfectly adapts to these demands as this technique permits food to be ready to eat even after a long shelf life while maintaining a high sensory quality. The previous research dealt with the effects of temperature, time and packaging conditions on the quality and shelf life of various culinary sous vide preparations, through the study of physical-chemical, microbiological and sensory features (Díaz, Nieto, Garrido & Bañón , 2008; Díaz, Garrido & Bañón, 2010) and the importance of the sensory analysis for establishing the shelf life of sous vide products had been proven (Díaz, Nieto, Garrido & Bañón, 2009). In addition, the incorporation of natural extracts (ie. rosemary, thyme, pomegranate, etc.) aimed to improve the quality and shelf life of sous-vide cooked meat, had been studied with interesting results (Nieto, Estrada, Jordán, Garrido & Bañón, 2011). Together, with Firo Vazquez ("El Olviar" restaurant, Moratalla, Murcia), they developed aromatic edible papers from different recipes featured on the menu, as well as several flavoured flours called Elaborinas ®(patent pending).

Normally, the field of Sensory Analysis had been used by food companies as a means of acquiring knowledge regarding the profile of their products, the variations that their products experience throughout the processing, their shelf life, or the result of adding new ingredients, among other information. However, lately this science has evolved toward the voice of consumers. More and more consideration was being given to how consumers perceived the products. Not only the hedonic perception (like or dislike) was taken into account, but also the sensory-discriminative perception within a given context (i.e., tableware and ambience). These topics were

included under the term ‘Molecular Gastronomy’, since the latter considered not only the transformation during cooking, but all the factors and facts included from the preparation of the recipe to its consumption.

The research group at the IATA-CSIC (Valencia, Spain) led by Susana Fiszman, dealt with topics such as the influence of the plate presentation (Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012), the effect of container texture on the perception of the quality of the food inside (Piqueras-Fiszman & Spence, 2012a), or how the container weight and other characteristics influenced the expected satiety (Piqueras-Fiszman & Spence, 2012b; Spence, Harrar, & Piqueras-Fiszman, 2012). Piqueras-Fiszman and Spence (2012b) demonstrated that modifying the weight of the food container could influence the perception of density and satiety (Figure 4) in the mind of consumers: the heavier the container the denser the content was perceived and the higher the expectations were about the satiating effect of the food.

Other novel methods were being researched in the consumer perception arena; for example, Mitterer-Daltoe, Queiroz, Fiszman and Varela (2014) used the eye-tracking technique to assess the perceived healthiness of fish plates cooked in different ways and served with several side vegetables. An R&D gastronomy group at Polytechnic University of Valencia was working on the textural, sensory and nutritional changes that took place in vegetables when cooked using different procedures (Iborra-Bernad, Philippon, García-Segovia & Martínez-Monzo, 2013; Iborra, Tárrega, García-Segovia & Martínez-Monzo, 2014). This research group focused on the improvement of the sensory features in restaurant desserts, evaluating the impact of replacing sugar with other sweeteners on the sensory profiles and the preference ratings for baked apple ice cream (García-Segovia et al., 2012). Recently, they had two protected patents relating to the development of

gastronomic products: 1) a process to produce flavoured eggs by using vacuum impregnation and 2) a process to produce a snack with soft tiger nuts. This research group co-organized the International Workshop in Creativity and Innovation in Haute Cuisine (Valencia, October 2010), whereby the presentations were summarized in a special issue of the Journal of Culinary Science and Technology (January, 2013).

Azti-Tecnalia Food Research Institute, together with the R&D Department of Mugaritz Restaurant, were in the process of developing new formulations, textures (Arboleya, Lasa, Olabarrieta & Martínez de Marañón, 2010) and foodstuffs for both restaurants and industry. This collaborative lab of ideas worked to create a practical way to optimize the chef's highly creativity methods in order to produce rational approaches to functional food product design from the initial idea. The "Engineering and Food Technology" research group at the University of Cadiz, together with chef Angel Leon (Aponiente restaurant, Cádiz, Spain), designed filtering equipment for soups and juices ("Clarimax" ®) using diatomaceous earth as a filter support. The filtration equipment reduced the broth turbidity by approximately 95% (NTU nephelometric units) without affecting the aroma and taste of the product. It also had the ability to degrease the soup by 80%, which could be very useful in preparing low-fat diets. Additionally, this research group had carried out an interesting study to try to unravel the composition of the Roman sauce, "Garum", and to provide information that would produce a similar product using current ingredients.

CONCLUSION

In sum, Spain has experienced a decade of overwhelming success regarding scientific and technology based cuisines, founded by many worldwide renowned

chefs, preeminently, Ferrán Adriá. Together with public media success, the technological and scientific activity in the culinary area has also accomplished numerous achievements. For example, Spain has been on the cutting edge in culinary technology innovation, with several successful patented kitchen appliances based on scientific knowledge. Spain also stands out in the collaboration between chefs and scientists with foundations, universities and research centres acting as coordinating nodes, committed to improving cooking techniques and ingredients. Additionally, Spain has been a key contributor to the scientific knowledge within the Molecular Gastronomy discipline with research groups devoting their efforts to different culinary topics and publishing their findings in international journals and books. With all these 'ingredients' in place, Spain faces a promising future in Molecular Gastronomy.

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Figure 1.- Gastrovac®: a worldwide distributed kitchen appliance for cooking under continuous vacuum and doing vacuum impregnation, developed by members of the University Polytechnic of Valencia (Spain).

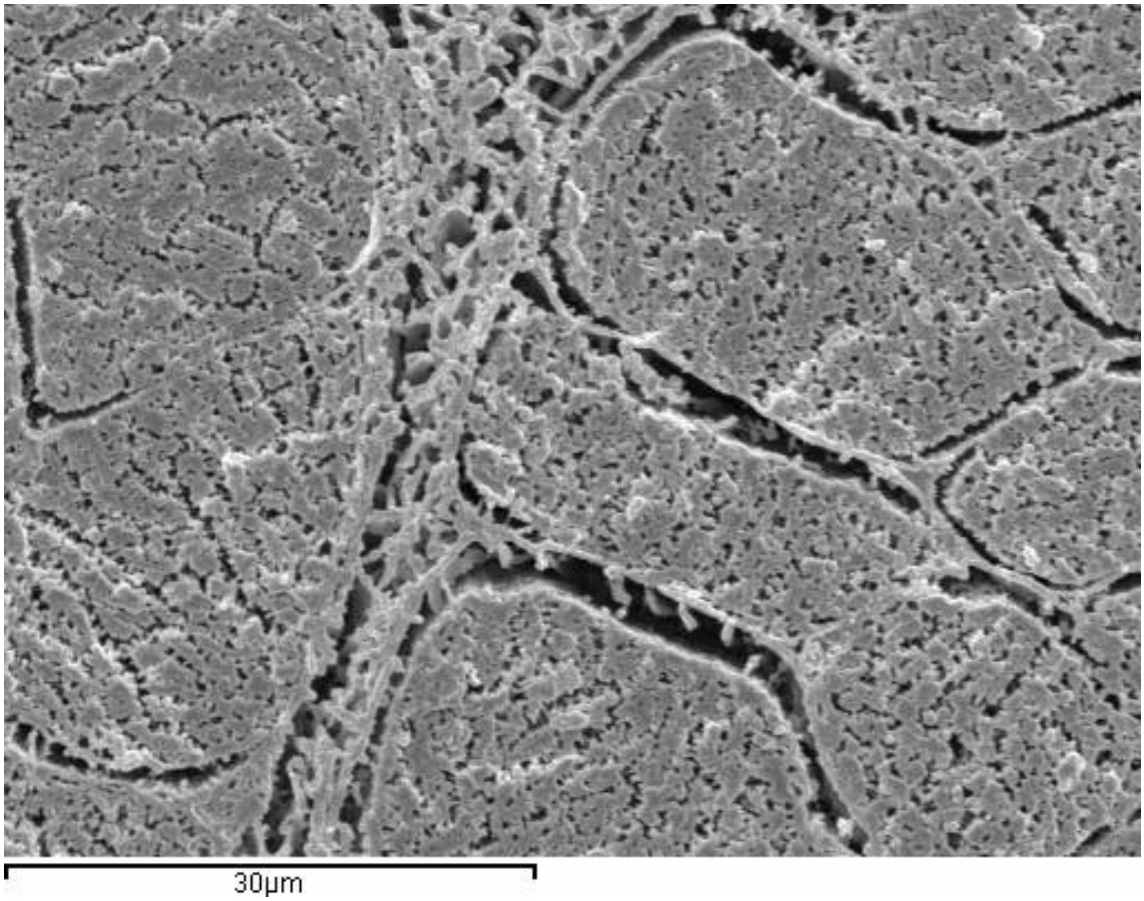

Figure 2.- SEM micrograph showing the formation of granular deposits in the endomysium and perymisium of lamb loin cooked sous-vide at 60ºC for 6 h (Roldán, 2010).

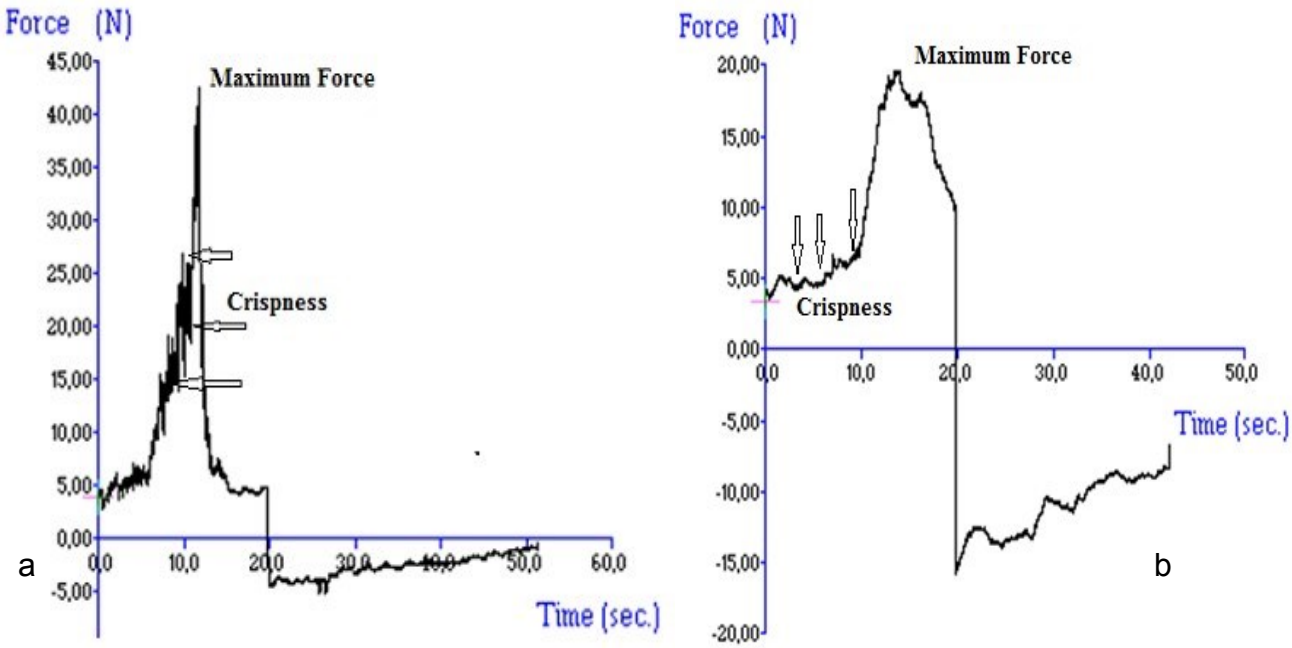

Figure 3 - Force versus time curves of a) dried and b) freeze-dried yogurt based foams compressed in a Kramer Shear cell, with representation of maximum force (N) and fracture events (drop in force higher than 0.049N), which represent crispness (Barata, 2012).

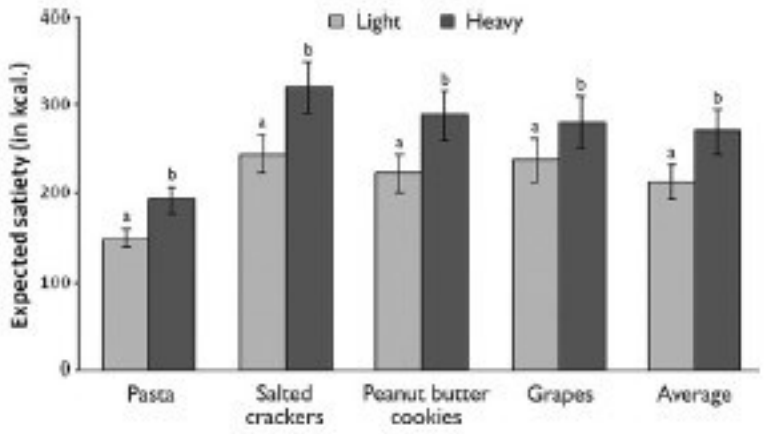

Figure 4.- Mean expected satiety scores (in kcal) for different foodstuff presented to the consumers in either light or heavy dishes (taken from Piqueras-Fiszman & Spence (2012b) with permission).