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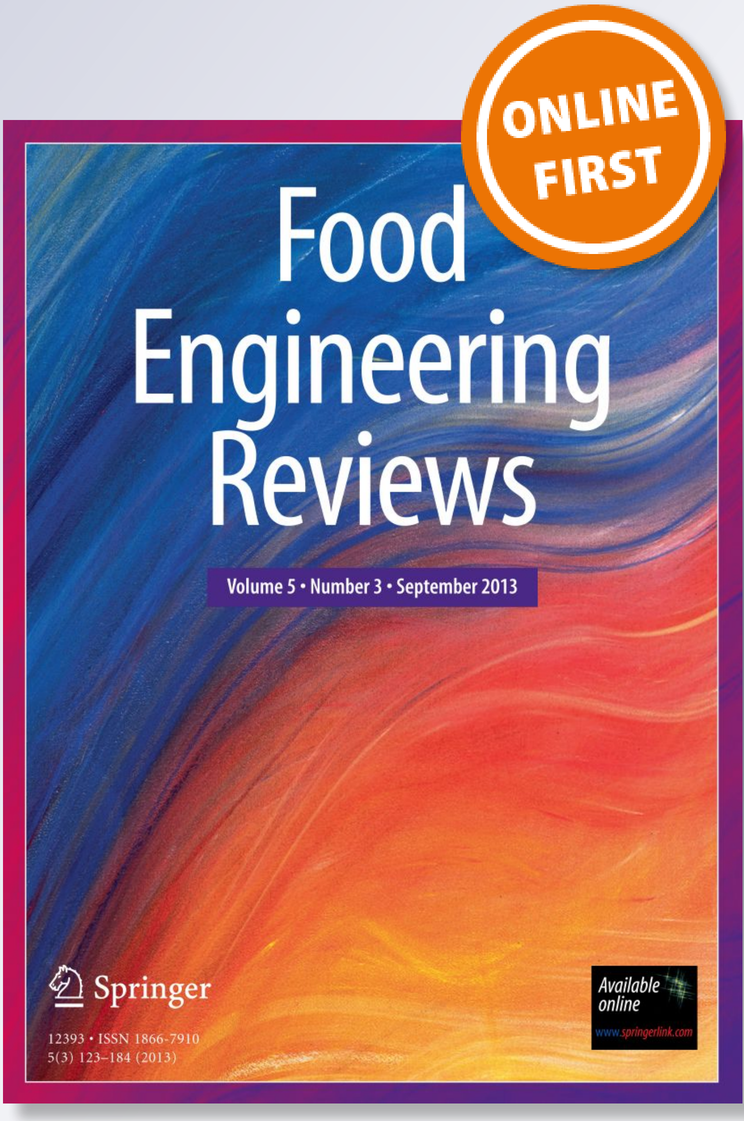

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REVIEW ARTICLE

Food Engineering in Ibero-America: the Contribution of the CYTED Program (1986–2005)

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Abstract

Between 1986 and 2005, the CYTED Sub-program on Food Preservation (CYTED-SFP) involved the collaboration of 11 Ibero-American countries, more than 60 multidisciplinary research groups and over 300 researchers. During this period, CYTED-SFP allowed the establishment of a thriving food engineering community through several international research projects and thematic cooperation networks. Scientifically, CYTED-SFP made important contributions in the areas of water management of foods and its practical applications as intermediate moisture foods, the preservation of foods by combined methods technologies, and minimally processed fruits and vegetables. CYTED-SFP played an important role in establishing food engineering as an academic sub-discipline in Latin America by the formation of advanced human capital (i.e., PhDs), training of technical personnel and students, initiation of academic programs in food engineering, and the generation of research articles, topical books, and educational material. Another legacy of the CYTED-SFP are the Congreso Iberoamericano de Ingeniería de Alimentos (CIBIA) congresses established in 1994, the last one (CIBIA-XI) celebrated recently in Valparaíso, Chile. CYTED-SFP is a unique example of international cooperation in the areas of food engineering and food technology.

Keywords Food engineering · Water activity · Intermediate moisture foods · Combined methods technology · CIBIA · Education · Scientific development · Latin America

Introduction

The study of foods in Latin America started in the mid-1900s in schools of chemistry and pharmacy at local universities, which were interested in the composition and chemical analysis of foods (bromatology) [1]. In the 1970s, medical doctors and food technologists became concerned about undernutrition of pregnant women and infants, and by the end of the twentieth century most emerging countries in the region exhibited significant improvements of their health and nutrition situation [2]. Courses in food science and food technology started to be taught mainly at Agricultural Sciences and Biological Sciences schools (e.g., Chile and Mexico) in the late 1960s, after young faculty returned to their home countries after graduating overseas.

Food engineering (FE) emerged in European and US universities as a discipline of its own in the 1950s, as the application of engineering principles to manufacturing operations in the food industry [3]. Mexico started the first course on food engineering at the *Instituto Politécnico Nacional* in Mexico City, as a part of the biochemical engineering syllabus in the late-1950s [4] and in the late 1960s, a MSc course in food science and food engineering. In 1963 the *Instituto Tecnológico de Monterrey* started offering a BSc degree in Biochemical Engineering in Food Technology (sic) at its branch in Guaymas, Sonora (http://www.itesm.mx/wps/wcm/connect/Campus/MTY/Monterrey/Acerca+del+campus/Historia+y+acreditaciones/1960-1969/). That same year, PLAPIQUI (a pilot plant for industrial chemistry) broke ground at the *Universidad Nacional del Sur* in Bahía Blanca, Argentina, which included a small group of chemical engineers interested in food processing. The first academic unit devoted specifically to food engineering in Latin America was established at ITAL (Sao Paulo, Brazil) in 1966, and later transferred to the UNICAMP campus in

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1972 under the name of Faculty of Food Engineering (https://www.fea.unicamp.br/). A Faculty of Food Industries was created at the *Universidad Nacional Agraria La Molina* (Lima, Peru) in 1969 (http://www.lamolina.edu.pe/portada/html/acerca/res_historica.html). In the mid-1970s, several chemical engineers with training in food technology started local research in food engineering and contributed consistently with publications in refereed journals. Food engineering in Spain became a discipline around the 1970s at the *Universidad Politécnica de Valencia* (UPV) and the *Universidad de Lleida*, and developed a food engineering syllabus under the leadership of professors with chemical engineering and agricultural engineering backgrounds [5, 6]. In Portugal, the first organized academic activities related to food engineering may be traced back to the *Escola Superior de Biotecnología* (ESB) established in 1983 at the *Universidade Católica Portuguesa* in Porto [7]. Agricultural engineering also played an important role in conceptualizing the role of the food chain linking production, postharvest, storage, and distribution of foods for small and medium enterprises in Latin America [8]. An early report describes the situation of agricultural engineering in Latin America and Europe in the late 1960s [9].

Early Contributions of the American Continent to Food Technology

The contributions of America (the *New World*) to alimentation started well before Columbus rediscovered this continent in 1492 and brought back many foods to Europe. It is unimaginable what the world's alimentation and gastronomy would be today without corn, potatoes, tomatoes, red peppers, avocados, cacao, etc. However, the supply of attractive edible materials has continued in post-Columbian times. Aborigines from what is now known as Paraguay used the leaves of the bushy shrub *Stevia rebaudiana* Bertoni to sweeten their foods ignoring their non-caloric properties, which are now amply appreciated as a potent low-calorie sweetener sold under the generic name of stevia [10]. In the beginning of this century, the Andean pseudo-cereal quinoa became actively traded in the world due to its excellent nutritional and culinary properties [11]. A similar situation is experiencing chia, a seed used by Aztecs and Mayas for the preparation of various meals and now being regarded as a promising functional food [12]. Recently, insects have been proposed as a source of good-quality protein and essential fatty acids, and Mexico is an example of an ancestral and sustainable consumption of these foods [13, 14].

Inhabitants of these lands not only selected edible materials through centuries but also developed ancestral technologies of food processing. The Mayans dried and roasted the seeds of the cacao plant (*Theobroma cacao*), ground them with a stone, and mixed into a drink with water, chile peppers, and cornmeal [15]. The Incas of the highlands of Peru froze potatoes during the cold nights and let them thaw in the sunny days, producing a natural freeze-dried *chuño* (black dried potatoes) or *tunta* (white dried potatoes) which were later ground into a flour [16]. Poisonous tubers (e.g., bitter cassava) and lupin grains were washed to remove the hydrocyanic acid and bitter alkaloids, respectively, making them edible [17]. The *nixtamalización* is thermal-alkaline process for preparation of a corn dough which in turn is used for preparation of *tortillas* (flat discs of dough cooked in a hot plate). This process dates back to the times of the early inhabitants of Mesoamerica and is still used to prepare these staple foods. The process has been subjected to modifications aiming at the nutritional enrichment of *tortillas*, for example, by adding soybean flour [18].

Early Research in Food Engineering in Ibero-America

Food dehydration and water relations in foods had been a major research topic among Latin American food engineers by the time the CYTED Program was conceived and launched in 1984. Publications in international journals covered subjects such as moisture sorption isotherms [19], modeling mass transfer in cellular foods and prediction of mass transfer coefficients [20], computer simulation of chemical and textural changes in dry foods during storage [21], and browning in the course of air drying [22]. Work on physical properties had also called their attention: rheology [23, 24], freezing [25, 26], and thermal conductivity [27]. Researchers at UPV (Spain) and *University of Porto* (Portugal) that joined CYTED were also interested in food engineering and drying [28, 29].

Origins of the CYTED Program

On occasion of the celebration of the V Centennial of the Discovery of America, an agreement was signed in 1984 by 19 Latin American countries plus Portugal and Spain (altogether known as Ibero-America) to launch a program on Scientific and Technological Cooperation for Development, the CYTED Program [30]. CYTED was structured into sub-programs dealing with specific thematic areas (e.g., biotechnology, biomass, microelectronics, environment, foods). The sub-program's activities were deployed through several instruments: research projects, thematic networks, workshops, coordination activities, and innovation projects (IBEROEKA).

The CYTED Sub-program *Treatment and Conservation of Foods* launched in 1986 (hereafter, Sub-program on Food Preservation or CYTED-SFP) had as main objectives to identify common problems, strengthen research activities, and enhance international competence in food technology in the region [30]. In 2005, the structure of the CYTED Program changed from subject-based sub-programs to thematic areas. This meant that the original scope of the CYTED-SFP focused on food technology changed to one encompassing the whole food chain from production (agriculture, husbandry, aquaculture, etc.) to consumption and involved also social concerns [31]. Another major event in the CYTED Program came in 2011 when Spain, which had been the major supporter of the activities for 27 years, drastically reduced the financial contribution to the Program. Nevertheless, after 30 years, CYTED-SFP has remained as the most relevant multinational scientific and technological cooperation program in foods in Ibero-America, and perhaps, the oldest in the world.

This article is based on a conference delivered at the 11th Ibero-American Congress on Food Engineering, CIBIA XI (October 2017, *Valparaiso*, Chile). Its main objective is to demonstrate how a long-term regional program in food technology/food engineering in the developing world contributed to the advancement of processing technologies as well as to the science of foods. It is also an attempt to summarize the contribution to food science, food technology, and food engineering of researchers from Ibero-America in the period from 1986 to 2005 within the context of the CYTED-SFP.

Intermediate Moisture Foods

Dehydration has been practiced since ancient times as a means of food preservation. In the absence of refrigeration, many countries of Latin America empirically developed safe, stable, and tasty foods which are not fully dry but contained 10–50% water. The key for their safety and stability is a water activity (a_w) ranging from 0.60 to 0.90; thus, they have been referred to as intermediate moisture foods (IMF) [32]. As it is typical of many food technologies, empiricism preceded the scientific understanding behind the processes. Water activity became a better descriptor of the role of water in low moisture foods in the early 1950s [33, 34]. The relation between the water content of foods, water activity, and the rate of several reactions became clear in the late 1960s [35], and a number of equations started to be fitted to sorption isotherms of several foods [36].

Some IMF are quite typical of the Ibero-American region. For example, *dulce de leche* or *manjar* (milk jam) is a sweetened dairy-based confectionary product popular in most Latin American countries whose a_w varies between 0.80 and 0.86 [37]. Charqui is a typical IMF product (a_w = 0.70–0.75) obtained by salting and sun-drying meat from different sources [38]. The identification of microbial stability as a result of a number of factors in traditional foods from Ibero-America allowed to establish the basis for the study of other IMF [39]. Hence, in the planning of a first CYTED-SFP project in foods, it became apparent that IMF were an attractive area of study for several reasons. First, many indigenous raw materials (fruits, meats, fish, etc.) processed at the artisanal level into IMF needed scientific and technological support to assure their safety and quality. Second, IMF were a means of extending the shelf life of local perishable foods and reducing their losses. Furthermore, the study of IMF involved many disciplines (food engineering, food technology, microbiology, sensory aspects, packaging, etc.); thus, it favored collaborative work. Another reason was that by the early 1980s, several researchers and their incipient groups in the region were already involved in the management of water in foods.

The main objective of Project XI.1, *Intermediate Moisture Foods Relevant to Ibero-America* (1986–1991), was to establish the technological basis (physicochemical, chemical, microbiological, biochemical, and nutritional) for the development of semi-processed and stable IMF consumed in the region [40]. Additionally, it aimed at the consolidation of an interdisciplinary and multinational group of food researchers []. Major scientific endeavors of this first CYTED-SFP project were to acquire information about traditional IMF consumed in Ibero-America and to advance in the use of fundamental concepts such as water activity and mass transfer during water removal. A classification of intermediate moisture foods consumed in Ibero-America was produced within the context of this action [41]. Also, an inventory of IMF, encompassing 337 products from 11 countries involving the contributions from 29 research groups, depicted for each IMF product a color picture in its consumption form, a proximate chemical analysis, the experimental and calculated a_w, as well as the marketing conditions [42]. The main a_w-depressing factors found were sodium chloride (salt) and sucrose (sugar), although low pH was also important in the stability of some vegetable sauces and fruit jams.

Methodologies for the Determination of a_w

A major subject of research in the early stages of the CYTED-SFP was the validation and proposition of methodologies for determining water activity. In this regard, the book by Iglesias and Chirife [43] was a pioneering publication of its kind, providing actual graphs of published sorption isotherms as well as recommending criteria for the compilation, representation of data, and the mathematical description of the isotherms. This book was a milestone in the water activity field and is still cited in the literature. Favetto and Chirife [44] proposed a theoretical methodology for predicting water activity of binary systems based on the molality of the components which was relevant to IMF. Ibero-American researchers studied and reported the temperature dependence of the sorption isotherms for selected foods [45]. Since the gravimetric method for determining the water activity-moisture dependence was a preferred technique, various works published in the late 1980s and early 1990s addressed the prediction of water activity of salt and sugar solutions ([46, 47]). A theoretical approach was developed to predict water activity of various saturated salt solutions that were used as standards in the a_w range of microbial growth [46]. In this context, Pollio et al. [48] published a method of prediction of the water activity of saturated salt solutions at relatively low temperatures that would be useful in cold storage of a number of foods. Several practical courses on food conservation by control of water activity as well as demonstrations by equipment manufacturers were held in different countries of the region, some of them attended by people from industry. A textbook (in Spanish) summarizing concepts of water activity and practical applications was published and widely distributed [49]. Later, a comprehensive book on water activity in foods edited by a member of several CYTED-SFP actions referred to aspects of a_w evaluation and practical uses investigated by Ibero-American researchers [50].

Food Preservation by Combined Method Technology

The second CYTED-SFP project X.2, *Bulk Fruit Preservation by Combined Methods Technology*, was carried out between 1992 and 1993. This project aimed at developing simple and affordable preservation technologies for bulk storage of fruits at ambient temperature to overcome seasonal constraints, diversify the amount of derived products, and reduce postharvest losses. Within this project, Tapia et al. [39] reported that in some cases a combination of hurdles such as low a_w and low pH would be sufficient for preserving fruit products in bulk. However, a control of several preservation factors such as a_w (0.94–0.98), pH (3.0–4.1), mild heat treatment (blanching), and reduced levels of antimicrobial agents (potassium sorbate, sodium benzoate, and sodium bisulfite) produced lightly processed fruit products which could withstand storage for 4 to 8 months [51]. The role of a_w on rubbery-glass transitions on the stability of foods was also investigated by Chirife and Buera [52]. Findings from this project, carried out by 114 investigators from eight countries, were disseminated in 36 peer-reviewed papers, 116 presentations at congresses and conferences, 69 undergraduate theses, 18 master's theses, 18 doctoral theses, 12 short courses, and 16 extension actions with the productive sector [53]. Two volumes on various topics on food technology and engineering were published (in Spanish) by the *Instituto Politécnico Nacional* from Mexico [54] having as contributors several researchers that had participated in CYTED-SFP actions.

By 1994, significant changes in the scope and depth of research in food engineering in Ibero-America had occurred when compared to the early 1980s (discussed before). Table 1 lists some of the subjects of invited lectures at the CIBIA I in 1995, after a decade since the inception of CYTED-SFP [55].

Minimally Processed Foods

Promising results emerging from the previous two CYTED-SFP projects originated a third project within the subprogram: XI.3. *Development of Minimal Processing Technologies for Food Preservation* (1995–1997), involving over 150 researchers from six Ibero-American countries. Minimally processed foods (MPF) offer the advantage of being subjected to a milder preservation process that provides sufficient shelf life and fresh-like quality. MPF are mostly produced by the so-called hurdle technology where a combination of several preservation factors (called hurdles) are applied at low levels to provide a good overall product stability during storage, and where the type of hurdles are product-specific [56, 57]. This technology offers the advantage that an extended shelf-life is achieved, and no refrigeration is required. Figure 1 is a photo taken on occasion of the visit of Prof. Lothar Leistner from the Federal Centre for Meat Research, Germany, to one of the meetings of the project in the frame of the 1993 IFT-Annual Meeting in Dallas, Texas. Several engineering problems were addressed within this project such as mass transport modeling in vacuum impregnation and atmospheric osmotic dehydration, effect of different treatments on microstructure-mechanical property relationships, and application of novel hurdles such as high-hydrostatic pressure, edible films, and natural antimicrobials. Major results were presented in Alzamora et al. [58–60] and Tapia de Daza et al. [61]. Some of the products obtained were high-moisture strawberries, papaya and melon pieces, papaya impregnated with passion juice, and avocado and banana purees with good overall acceptability after 1 month of storage at 15 °C. This project ran in parallel with an STD project funded by the EU on MPF from tropical fruits (1995–1998) and in which MPF were, since those years, related to food structure [58–60], a subject that was later the subject of a project on structure-function relationships in dehydration and storage discussed below. It was quite remarkable and reassuring that in 1997, a delegation

Table 1 Themes of invited lectures to the first Ibero-American Congress on Food Engineering, CIBIA I (1995)

- Sorption isotherms
- Microstructural analysis applied to food engineering
- Minimal processing of foods
- Structural changes during minimal processing of fruits
- Thermal properties relevant in food sterilization
- Application of pulsed electric fields in food processing
- Modeling of vacuum impregnation and osmotic dehydration
- Packaging design and storage stability modeling
- Educational software for food engineering
- Formation of human resources and curricula in food technology/food engineering

Fig. 1 It was a common practice to invite distinguished international researchers to the CYTED-SFP reunions taking place on occasion of international meetings. In the photo (1993 IFT-Annual meeting, Dallas Texas), from left to right: E. Parada-Arias (coordinator of CYTED-SFP), Prof. L. Leistner, J. Welti-Chanes, J. Chirife, M. S. Tapia, J. M. Aguilera, and G. V. Barbosa-Cánovas

of CYTED-SFP groups dealing with IMF and MPF were invited to comment on their findings at the R&D Center for Unilever in *Colworth House*, England.

Other Activities and Outputs in Food Engineering

In the period 2000–2005, four CYTED-SFP projects were related to food engineering: structure-property relationships in food dehydration, development of calculation tools for food engineering, preservation of cut vegetables, ingredients with specific functionalities, and emerging technologies for food preservation. Relations between structure and properties of dehydrated foods had been a major area of interest in Ibero-America since the 1990s. The project XI.13, *Structure-property Relationships in Food Dehydration and Storage* (1999–2002), involved researchers from six countries and covered the relation between microstructure and texture in minimally processed fruits [58–60] and in dehydrated foods [62]. An international conference *Iberdesh: Process, Structure and Functionality* took place in Valencia, Spain, in 2002, to revise advances and relations in a wide variety of subjects such as microscopy techniques, microstructure, glass transition, hydrodynamic mechanisms of impregnation, and fractals. A special number of *Food Science and Technology International* (volume 9, number 3, 2003) contained 14 articles selected from *Iberdesh 2002* dealing with various aspects of food dehydration with emphasis on structural characteristics and phase transitions of a number of food materials.

The project XI.22, *Technology Development of Fresh-cut Produce* (2003–2007), had the objective of assessing technological treatments for different fresh-cut produce to increase their consumption and safely preserve the quality. Researchers from eight countries participated in this action which addressed the application of various processing technologies such as ultraviolet irradiation, edible coatings, modified atmospheres, and active packaging to increase the shelf life and convenience of fresh fruits [63], for instance, fresh cut papaya [64].

A project XI, *Development of New Functional Ingredients* (2000–2003), aimed at developing basic and applied knowledge on the interactions between protein and polysaccharides as well as obtaining sensory-acceptable functional foods. It involved researchers from six countries. In this project, the physicochemical, functional, and stability properties of the products (in dehydrated form) were studied and the applications of the ingredients in foodstuffs of industrial interest were explored. Important results of collaborations were presented by Baeza et al. [65, 66] and Martínez et al. [65].

Following the success of previous CYTED-SFP on minimal and combined processing, the project XI.15, *Emerging Technologies for the Preservation of Foods Important to Ibero-America* (1999 to 2002), was carried out by researchers from four countries. The objectives were to apply emerging technologies identifying key processing variables and their combination to achieve microbial stability as well as to carry out process-engineering calculations and develop predictive models for microbial growth. Relevant results were published in the book *Novel Food Technologies* [68] and as book chapters by Alzamora et al. [69], Alzamora et al. [70], and Dorantes-Álvarez et al. [71] or as journal articles [72].

As explained before, the CYTED-SFP included not only research projects but also thematic networks. A network on *Relevant Physical Properties of Foods for Industrial Design* (1992–1997) convened researchers from eight countries to compile methodologies for the determination of physical properties as well as to generate data for Ibero-American food products. A number of publications were produced within the network, including a compilation of rheological terminology in Spanish and Portuguese languages (Aguilera and Duran 1996) and a book edited by Alvarado and Aguilera [73] on methodologies for the determination of physical properties of foods, published by Editorial Acribia (Spain).

The network of *Food Engineering for the Development of the Regional Industry* (1992–1995) comprising 11 countries and 20 researchers targeted the strengthening of the industrial capacities of the region in food engineering. From outputs of this network, the project XI.11 *Calculation Tools for Food Engineering* (1997–2000) was conceived to develop calculation modules and simulation packages for the main unit operations used by the food industry. Nine workshops on calculation tools for food engineering took place in different countries, and a set of eight manuals were produced containing the theoretical framework and software tools for food engineering calculations. This material is still used by students, professors, and industrial professionals and remains available at https://www.upv.es/dtalim/herraweb.htm (consulted 10 November 2017).

The CIBIA Congresses

In the early 1980s, opportunities to exchange ideas around food engineering were almost non-existing in Latin America. A few national food science and technology societies operated at that time (AATA, Argentina; SOCHITAL, Chile; SBCTA, Brazil; ATAM, México, etc.), but no interactions had occurred at the regional level. As an initiative of the CYTED-SFP, the first Ibero-American Congress on Food Engineering (CIBIA) was held at the *Universidade Estadual de Campinas*, Sao Paulo, Brazil, from November 5 to 9, 1995. These biannual meetings have been ongoing uninterrupted to date, and nine countries in the region have hosted the CIBIA (Table 2). Helping in the promotion of food engineering where the discipline was emerging and consolidating it in others, a characteristic of CIBIA was the invited participation of international experts in the various aspects of food engineering.

CIBIA has been an instance of great convocation at the Ibero-American level, and a forum to share and exchange viewpoints with important invited researchers in food engineering from around the world. The congresses have promoted food engineering in the host countries and have been a unique opportunity for young researchers and graduate students to present their works. Presentations at most CIBIA were divulged either as Conference Proceedings or as books published by reputed editorial houses, such as those from CIBIA I [55], CIBIA 2 [74], and CIBIA 5 [75]. Presentations at CIBIA have also been presented in special issues of engineering journals as those emerging from CIBIA 4 (*Journal of Food Engineering*, volume 67, numbers 1–2, 2005, guest edited by J.M Aguilera and R. Simpson). Organizing CIBIA facilitated the hosting in Ibero-America of important international congresses such as ISOPOW 5 (Peñiscola, Spain, 1987), ISOPOW-Practicum 2 (Puebla, Mexico, 1992), ICEF 8 (Puebla, Mexico, 2000), ISOPOW 9 (Mar del Plata, Argentina, 2000), and ICEF 10 (Valparaíso, Chile, 2008). Later, the region was the venue of ISOPOW and ISOPOW-Practicum 11 meetings (Jurica, México, 2010) and the 16th IUFoST World Congress (Iguassu Falls, Brazil, 2012).

A good way to dimension the relevance of CIBIA is to compare it with the International Congress on Engineering and Food (ICEF) which is the leading event on food engineering worldwide. Figure 2 depicts the number of presentations in both events from 1995 to 2004. Except for ICEF 11 held in Athens that marked a peak of 1146 oral and poster presentations, most CIBIA attracted similar numbers of submitted works as ICEF. In the period 1995–2004, the average number of submitted presentations for ICEF was only 23% higher than at CIBIA. Evidently, CIBIA were mostly held in Latin America, which generally meant higher travel costs for researchers from overseas and were purposely planned to take place in some countries with a small food engineering community; thus, student participation was low. It is remarkable that the coordinators

Table 2 Ibero-American Congresses of Food Engineering—CIBIA (1995–2017)

Event, place, and president of organizing committee	
CIBIA 1: Campinas, Brazil, 1995; Enrique Ortega Rivas	CIBIA 7: Bogotá, Colombia, 2009; *Integrating food engineering and wellbeing.* Gloria González
CIBIA 2: Bahía Blanca, Argentina, 1998; Cristina Añón and Jorge Lozano	CIBIA 8: Lima, Peru, 2011; *The key to innovation.* Carmen Velezmoro
CIBIA 3: Valencia, Spain 2001; *Food engineering: New frontiers.* Pedro Fito	CIBIA 9: Valencia, Spain, 2014; *The challenges of food engineering.* Pedro Fito
CIBIA 4: Valparaíso, Chile, 2003; *Projecting food processing.* José M. Aguilera	CIBIA 10: Montevideo, Uruguay, 2015; *Food engineering at its pinnacle*. Rosa Márquez
CIBIA 5: Puerto Vallarta, México, 2005; *Towards an integrated vision of food engineering.* Gustavo Gutiérrez.	CIBIA 11: Valparaiso, Chile, 2017; *Processed foods for health and wellbeing*. Sergio Almonacid
CIBIA 6: Ambato, Ecuador, 2007; *A better use of our foods.* Juan de Dios Alvarado	

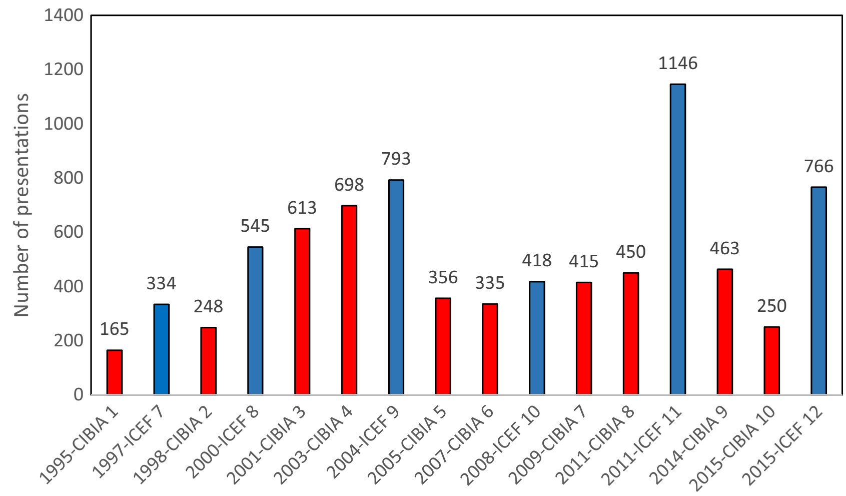

Fig. 2 A comparison of presentations at CIBIA (Ibero-American Congress on Food Engineering, in red) and ICEF (International Congress on Engineering and Food, in blue) in the period 1995–2015

of CYTED-SFP actions were also presidents of ICEF 8 and ICEF 10 which took place in Mexico and Chile in 2000 and 2008, respectively, and editors of the books produced as a result of these conferences [1, 76].

Some Impacts of the CYTED-SFP

Viewed in perspective, the CYTED-SFP had several noteworthy quantifiable and intangible impacts on the Ibero-American food engineering community during the period 1986–2005 (and beyond).

- Among the tangible results, we can mention a number of thesis, scientific articles, books, manuals, catalogs, and bulletins produced by members of the CYTED-SFP actions, some of which were mentioned in the previous sections. Table 3 shows some impressive results in terms of researchers involved and publications for the period 1986–1998.
- It contributed to the regional integration and cohesion of many research groups of the food technology/engineering community in Ibero-America, and consolidated a cooperation culture which has transcended into the present. It encouraged solidarity by mentors and advanced research teams in helping and promoting lesser developed groups.
- The CYTED-SFP contributed to the establishment and strengthening of academic curricula in food engineering and the consolidation of graduate schools with doctoral programs. As shown in Table 4, by the year 2000, there were over 100 undergraduate programs in food engineering in Latin America [78]. Also, many Latin American researchers were educated (PhD degrees), formed, and/or trained in Europe and the USA under the umbrella of CYTED-SFP, particularly at *Universidad Politécnica de Valencia* and *Washington State University*.
- CYTED-SFP permitted the presentation of groups in research calls by international funding sources (OAS, INCO-UE, STD), participation in international networks and associations (ISFE, IUFoST, ISOPOW, ISEKI, etc.), and the organization of foreign symposia such as Food Preservation by Combined Methods (IFT 1991) and Innovation in Traditional Foods (EFFoST-2005).
- Another major output was the dissemination of results of the CYTED project and congresses as perspectives and thematic books published by major editorial houses. Table 5 summarizes the title of some of the most relevant books, authors, or editors that had been associated with CYTED-SFP in the period, and the year of publication.
- As explained before, CYTED-SFP was aimed at strengthening research activities, human capital formation, and international competences in food technology and engineering. Thus, the industrial sector benefited from world-

Table 3 Summary of accomplishments of the CYTED-SFP (1986–1998)

Project	Years	Countries	Researchers	Publications	References
IMF	1986–91	11	348	141	[77]
BPF-CMT	1991–94	6	114	50	[52]; [78]
MPF	1995–98	6	153	100	[79]

IMF Intermediate Moisture Foods Relevant to Ibero-America, *BFP-CMT* Bulk Fruit Preservation by Combined Methods Technology, *MPF* Development of Minimal Processing Technologies for Food Preservation

Table 4 Undergraduate programs in food engineering in Latin America in the year 2000

Country	Number
Brazil	30
Mexico	28
Argentina	18
Chile	11
Peru	7
Colombia	6
Venezuela	5
Bolivia	4
El Salvador	2
TOTAL	> 100

Source: Welti-Chanes et al. [78]

class graduates in food science and food engineering, the training of their technical personnel through courses and other dissemination activities, and access to databases, advanced laboratory equipment, dedicated software, and expertise in universities. Unfortunately, at the time SMEs involved in food processing did not have consolidated R&D groups (and food multinationals depended on their central R&D departments) to completely assimilate the results of research emanating from the CYTED-SPF. However, inspection of projects financed by the sister CYTED program, IBEROEKA (aimed at technology transfer to the industrial sector), reveals that in the period 1998–2005 some of the topics were related to CYTED-SFP: salting of cured hams, sous-vide technology for extended shelf life, ready-to-eat fresh fruits, extraction of stevia, ingredients for the meat industry, fish analogs, etc. (http://www.cyted.org/es/proyectos_certificados).

Future Outlook in Food and Nutrition for the Latin America Region

Latin America and the Caribbean have the greatest agricultural land and water availability per capita in the planet. With 15% of the world's land area, it receives 29% of global precipitation and has 33% of globally available renewable resources [79]. The region is a net world supplier of foods (16% exports versus 4% imports in 2014), but exports consist mostly of commodities such as soybeans (50%), bananas (65%), coffee (47%), and meat (30%) [80]. Obesity and related non-communicable diseases have become of major public health concern, superseding undernutrition problems still remaining in some areas. Mexico and Chile are now among the world's fattest nations, and up to 25% of children in Latin America are obese or overweight [81]. Although the region produces enough food to meet the needs of its population, sustainable and nutrition-sensitive food systems and science-based public policies need to be implemented [82]. On the production side, increasing the productivity of small farmers and perfecting the technology transfer to food-related SMEs

Table 5 Some books published by authors or editors participating in the CYTED-SFP

Title	Authors or editors	Publisher	Year
Food Preservation by Moisture Control—Fundamentals and Applications	Barbosa-Cánovas GV, Welti-Chanes J	CRC Press, Boca Raton, FL	1995
Dehydration of Foods	Barbosa-Canóvas GV, Vega-Mercado H	Springer, NY	1996
Food Engineering 2000	Barbosa-Canóvas GV, Fito P, Ortega-Rivas E	Springer, NY	1997
Microstructural Principles of Food Processing and Engineering	Aguilera JM, Stanley D	Aspen Publishers, Gaithersburg, MD	1999
Engineering and Food for the 21st Century	Welti-Chanes J, Barbosa-Cánovas, GV, Aguilera JM	CRC Press, Boca Raton, FL	2000
Minimally Processed Fruits and Vegetables: Fundamental Aspects and Applications	Alzamora SM, Tapia MS, Lopez-Malo	Aspen Publishers, Gaithersburg, MD	2000
Trends in Food Engineering.	Lozano JE, Añón C, Parada-Arias E, Barbosa-Cánovas GV	Technomics Publishers, Lancaster, PA	2000
Métodos para Medir Propiedades Físicas en Industrias de Alimentos	Aguilera JM, Alvarado JD	Acribia, Spain	2001
Novel Food Technologies	Barbosa-Canovas GV, Tapia MS, Cano P	Marcel Dekker, NY	2005
Water Properties of Food, Pharmaceutical, and Biological Materials	Buera MP, Corti HR, Welti-Chanes J,. Lillford PJ	CRC Press/ Taylor and Francis, FL	2005
Fruit Manufacturing: Scientific basis, engineering properties, and deteriorative reactions of technological importance	Lozano JE	Springer, NY	2006
Food Engineering: Integrated Approaches	Gutiérrez-López GF, Barbosa-Cánovas GV, Welti-Chanes J, Parada-Arias E	Springer, NY	2008

will diversify the food export matrix, add value to products, and give support to incoming entrepreneurs.

Conclusions

The CYTED-SFP launched in 1986 and involving many multidisciplinary research groups in Latin America, Spain, and Portugal marked a turning point in food engineering research and education for the region. We believe that this success was based on several factors: (i) the clear identification of unique opportunities based on local problems related to foods; (ii) the commitment of dedicated research groups working under a multidisciplinary approach (food science, food microbiology, food engineering); (iii) a reduced but consistent financing of coordination activities for over 20 years from the CYTED Program and national research funding agencies; (iv) a self-imposed benchmarking for quality output in the form of journal articles, books, periodical bulletins, congresses, and courses, and; (v) the visionary leadership to coordinate and manage the activities of the program.

Today, many emerging areas of the world share common problems related to foods that may be advantageously addressed by regional cooperation programs. Among these subjects are food safety, food security, sustainability, technology innovation, etc. Modern communication technologies non-existing at the time of CYTED-SFP in the form of webinars, online courses, and interactive systems for learning may facilitate the scientific cooperation between countries.

Lastly, there are some researchers whose important contributions to CYTED-SFP have not been referred to explicitly or cited adequately in this article. In addition, several food engineers in the region had relevant impacts during the period but were not directly involved in the CYTED-SFP. We apologize to them but hope they will understand the space limitations imposed when writing a manuscript like this.

Dedication The authors dedicate this manuscript to Dr. Efren Parada-Arias, professor of the *Instituto Politécnico Nacional* (Mexico). He was the coordinator of CYTED-SFP during the period 1985 to 1999 and provided the vision, talent, and exceptional leadership that made possible most of the accomplishments previously described. Above all, he was (and is) a great human being….

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