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Food Engineering Education in Mexico, Central America, and South America

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ABSTRACT: The teaching of food engineering (FE) in Mexico and Central and South America began more than 50 years ago, initially with programs related to Chemical Engineering and Chemistry. The first programs clearly denominated as FE emerged during late 1960s and early 1970s; the support of the Organization of American States (OAS) and United Nations (UN) in some cases and the Science and Technology for Development Program (CYTED), launched in the early 1980s, stimulated and strengthened the development of FE. Relevant developments on FE in Latin-America can be traced down to topics such as: evaluation of physicochemical and transport properties, water activity, high and intermediate moisture foods, food drying, modeling and simulation of processes, hurdle technology, minimal processing, and emerging technologies. At present, FE Education in Latin-America interacts and coexists with the new paradigms related to the design of preservation processes and the development of Biotechnology.

Geographic, economic, and social situation of the region and its relation with the development of food engineering (FE).

Despite that globalization processes are eliminating borders, making countries closer and attempting to put in place a common language for a better understanding and solving of problems, at present time, historical, cultural, and economic differences still persist along with the ignorance of what communities are. For these reasons, before discussing the matter of this paper, the regional subject of this discussion is described in terms of its geographic, economic, and social situation. In geographic terms, Mexico is part of North-America; Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama belong to Central-America, while Colombia, Venezuela, Ecuador, Guyana, Suriname, French Guyana, Peru, Bolivia, Brazil, Paraguay, Uruguay, Argentina, and Chile constitute the whole of South-America. The problems of North-America (in this case Mexico), Central-America, and South-America are usually different in terms of production, handling, and preservation of foods. The whole region has more than 520 million people, with small countries, such as Belize that has 256 thousand inhabitants, and big, such as Brazil or Mexico that have about 175 million and 100 million inhabitants, respectively. Mexico has been impacted in recent years by the North-America Free Trade Agreement (NAFTA), producing a change in food consumption trends by increasing, for instance, the overall consumption of refrigerated or frozen foods in Northern and Central Mexico or by strongly assuming the fast food concept. On the other hand, food consumption patterns are basically determined by the fresh and local industry markets in Southern Mexico and in the major part of Central-America. On the other hand, South-America is a mixture of habits, traditions and tendencies as far as the consumption of foods is concerned. Thus, Argentina and Chile and, to a lesser extent, Brazil, Colombia, and Venezuela, are important consumers of processed foods produced in those countries or imported from Europe and United States, while the rest of the South-American countries consumes mainly locally produced fresh or processed foods. In the short term, the free-trade agreements established in Central and South America will influence the food consumption and industrialization patterns.

Social and economic differences among the countries in the region are still great, with lacking social groups and a limited access to a sufficient and balanced feeding along with severe malnutrition problems (caloric, protein, and vitamin and mineral deficiencies). Malnutrition problems in other sectors of society with adequate purchasing power are also present in these countries. Foodborne diseases outbreaks are still an important problem, needing immediate sanitary solutions.

Many countries in the region are important producers of fruits and vegetables, as in the case of Chile, Brazil, Central-American countries, and Mexico. However, in most cases, products are exported without transformation to the United States, Europe, and Japan. Other countries such as Argentina and Uruguay are important meat exporters (most of it frozen), and countries from Central-America and Mexico do well in the refrigerated or frozen sea products markets. The food processing industry in the region has grown in recent years, but some countries still tend to produce foods (harvest or breed) which do not support the transformation steps.

According to a study presented by Tapia and Welti-Chanes (1999), out of the 50 more important food and beverage industries in the region (based on their sales volume), 42% are located in Brazil, 9% in Mexico, 6% in Argentina, 5% in Chile, 5% in Colombia, 2% in Peru, and 2% in Venezuela. Also, the 3 largest industries (Brahma, Antartica Paulista, and Femsa de México) produce beer or soft drinks. In fact, out of the 25 greater industries in the region, 10 produce beer and soft drinks, and from the total annual sales of these 25 companies, ($45 billion) 44% come from the beer and soft drinks industries. In another study conducted recently by Bressani (2000), it was demonstrated that 23% of the food industry in Central-America is represented by the beer and soft drinks industry, 19% by the sugar industry, and 17% by coffee industry.

Except for the large transnational companies (Nestlé, Unilever, Cargill, Parmalat, and so on), and some regional ones, (Bimbo and Gruma in Mexico, Molinos del Río de la Plata in Argentina, MAVESA-POLAR in Venezuela, and so on), most of the food processing industry is medium or small sized compared to the size of similar industries in other parts of the world. The mentioned study (Tapia and Welti-Chanes 1999) also showed that research and development performed by most of the big food companies in the region is modest, generally restricted to change flavors to adapt to local tastes, size and package. Most of new products and processes are developed in their headquarters in the United States or Europe.

Therefore, we find a region with very particular problems related to production, preservation, and consumption of foods. This scenario should, consequently, strongly influence the structure of study and research programs in Food Engineering. Some opportunity areas or problems are:

(1) Countries that are great producers and exporters of fresh foods
(2) Most of the countries import basic foods (grains and cereals), except for countries as Argentina
(3) Countries that import transformed and processed foods, which have little commercial exchange within the region
(4) An important portion of the population of the region risks serious malnutrition
(5) Very different Gross National Product (GNP) per capita among countries, and thus different purchasing power
(6) Post harvest losses and contamination problems of foods (microbial or toxic products contamination)
(7) An underdeveloped local food industry
(8) Investigation in universities or research centers not related to industry problems, not connected with local industries, and/or divorced from State policies

What should be done then, in teaching and research in this area? Response to this question requires knowing the historical evolution and actual status of this area of knowledge within the Latin-American region.

Historical Background, Evolution of Teaching, and Research of FE in the Region.

Teaching of Food Science and Technology, in particular Food Engineering programs, originated in the late 1960s and early 1970s when the first Food Engineering B.S. (Licenciatura) programs began in Brazil, Argentina, and Mexico. These programs were a mixture of the structures of the European Chemical Engineering programs and Food Engineering programs from the United States. But, before this period and since 1940, food engineering was indirectly taught in Latin-America within Agriculture, Chemical Science, and Chemical Engineering programs, giving courses on postharvest physiology and composition and stability changes of products of animal products and sea products. Some of these courses already included food handling and preservation principles, as well as unit operations applied to specific processes such as sugar, coffee or oil extractions; heat exchange and flow of fluids for milk and juices pasteurization; dehydration of fruits, meat, and fish; as well as the study of other traditional processes to obtain intermediate moisture foods through salting and sugaring techniques. The compositional characterization of foods began in the 1940s with the purpose of knowing the nutritional properties of the products. Studies of microbiological nature came on as a way to stabilize foods and avoid foodborne diseases.

Biochemical Engineering programs appeared during the late 1950s and early 1960s. Such programs were a mixture of Biology, Chemistry, and Chemical Engineering programs and generated professionals that did not study in depth any of the mentioned areas. The specialties in Chemistry and Food Analysis within the Chemistry and Pharmacy B.S. programs appeared by those years too. In the middle 1960s the Biochemical Engineering programs were restructured by people who studied Food Science and Technology in the United States and Europe, and were reoriented in such way that the first formal courses in Food Processing, Food Chemistry, and Food Microbiology appeared. These biochemical engineers were prepared as food technologists, not as engineers, because, in order to have special courses related to food, other courses on Mathematics and Chemical Engineering Fundamentals were eliminated.

As mentioned before, the first programs formally called Food Engineering emerged in the middle 1960s; the Univ. de Campinas in Brazil and the Univ. de las Américas-Puebla in Mexico are 2 of the pioneer institutions in this field. In the particular case of the Brazilian institution, the program began in 1969 in the Instituto de Tecnología de Alimentos (ITAL), supported by the local government of São Paulo. In 1972 such academic program moved to the Univ. de Campinas (UNICAMP) where the FE Faculty was created. This faculty can be considered as the first great teach and research unit within the food area that operated in Latin America. The UNICAM program initially operated thanks to the support of the Organization of American States (OAS). The first courses on Transport Phenomena applied to Foods, Food Physical-Chemistry, Unit Operations in Foods, and Design of Food Processing Plants were structured. These courses showed the influence of the professors of these programs that obtained their Master and Doctorate degrees in the United States, Germany, France, and England, and transferred the structure and knowledge obtained in those countries. As mentioned by Bressani (2000) for the case of the beginning of the academic Food Technology programs in Central-America: "the activity was initiated not as a result of a particular interest of the food industry existing at the time, but as the need to contribute to the solution of a number of problems existing in the area, such as the need to add economic value to agricultural products through industrialization, reduce postharvest losses in a number of foods along the food chain, contribute with the development of high nutritional quality of foods within the reach of low income groups and children, eliminate nutritional deficiencies, and develop locally accepted food presenting convenience to the consumer."

The interaction among professors and researchers in the region was minimal during the mentioned stage, and even when the structure of the academic programs is very similar, the collaborative work among Latin-American universities and countries was done by chance. The most important exception during this period are the programs of UNICAMP in Brazil, that with the support of the OAS and even when living in difficult political situations in most of the Central and South American countries a scholarship program was maintained to enroll a large number of postgraduate students from these countries in 2-year training programs. The Master and Doctorate programs that appeared in Brazil during the middle 1970s and early 1980s made some professors of the other countries of the region move to Brazil and obtain their degrees there. Then they went back to their countries and influenced the structure and content of Food Engineering programs based on the Brazilian approach, which is related to the evolution of this area of knowledge mainly in the United States and to a lesser degree in Europe. During this period, research groups of institutions such as the Univ. de Buenos Aires and of the Pontificia Univ. Católica de Chile consolidated working mainly in projects related to food dehydration and water activity concepts. In the same way, 2 research centers, ITAL and the Instituto de Nutrición de Centro América y Panamá (INCAP), were supported in great extent since their creation by the United Nations Developing Program (UNDP). Their contributions encouraged the advance of the Food Science and Technology in the region. In the particular case of ITAL, the research works on water activity, sorption isotherms of different foods, and the developments regarding thermal treatment, which generated some of the first publications on FE in Latin America, are outstanding.

During the 1980s, and under a political environment markedly stable within the region, the cooperative actions of the Science and Technology for Development Program (CYTED), through the Subprogram "Food Treatment and Preservation", began to impact the development of academic and research programs. CYTED has had an important effect on the interaction among universities and research centers, and consequently has impacted the structure of academic programs.

Treatment and Preservation of Foods, diameter of 16 Sub-Programs established within CYTED, was launched with the clear objective of developing technologies to preserve and enhance the quality of foods and nutrition in the region. Its first project, which started in 1984, was Project XI.1 "Development of Intermediate Moisture Foods Important for Ibero-America." Some 300 researchers, based at 60 research centers in Argentina, Brazil, Costa Rica, Chile, Cuba, Mexico, Puerto Rico, Spain, Nicaragua, Uruguay, and Venezuela, took part in this project (Parada-Arias 1995). Over 4 years, the principles and concepts of water activity manipulation, as well as other concepts of food preservation, such as hurdle technology, were shared and taught among the research groups. Besides the important scientific production generated through the project, along with courses, seminars, and scientific exchange, the number of publications related to a_w and combined methods of preservation increased, not only from the groups involved in the Project XI.1, but also by a number of groups which indirectly benefited from its actions. During this stage, the contributions of the groups of the Pontificia Univ. Católica de Chile and of the Univ. de Buenos Aires, Argentina, were very important to support the development of the research groups from other countries. The contribution of the Univ. Politécnica de Valencia, Spain, since this project and along the whole CYTED program, has been very important.

From its beginning, the subprogram promoted enhancement of academic programs by strengthening them with important knowledge-based components that would result in sound and better prepared food technology professionals. This is reflected in the topical areas the subprogram has addressed from 1984 to 2001 (see Table 1 and 2).

After Project Xl.1 ended in January 1991 and its results were analyzed, it became clear that continued cooperative research on bulk fruit preservation using combined methods was needed, giving rise to Project XI.2. This project was headed by the Mexican groups. The goals of this project, carried out during 1992 and 1993, were to reduce postharvest losses, increase the added value of raw materials, and identify a correct and more efficient use of the installed capacity of the fruit processing industries of the region. One hundred and fourteen investigators from 8 countries staffed project XI.2. Findings from the study were disseminated in 36 papers in scientific peer-reviewed journals; 116 presentations at congresses and conferences; 69 undergraduate theses; 18 master's theses; 18 doctoral theses, 12 short courses, and 16 approaching actions to the productive sector. (Welti-Chanes and Vergara-Balderas 1995). These numbers give some indication of the impact of the CYTED Project on academic curricula and research. CYTED Project findings strongly influenced the structure and contents of the academic programs of the participating institutions. In addition, it helped stimulate interest in the region in learning how to apply the basic principles of fruit preservation in a combined methods approach, in order to retard physical, chemical, and microbiological deterioration. The intelligent use of preservation factors, a_w, pH, blanching, and controlled levels of antimicrobial agents among others, for obtaining lightly processed fruit products began to be a common topic in academic programs, theses, meet-

Table 1—Pre-Competitive Research Projects Conducted in the Sub-Program "Food Treatment and Conservation" (1984-2001)

Project nr	Project Name
XI.1	Development of Intermediate Moisture Foods on Interest for Ibero-America
XI.2	Bulk Preservation of Fruits by Combined Methods
XI.3	Development of Minimal Processing Technologies for Food Preservation
XI.4	Development and Application of Parameters of Sensory Evaluation of Foods
XI.5	Effect of the Conditions of Process and Storage on the Physical Properties of Foods
XI.6	Obtaining and Characterization of Dietary Fiber for their Application in Foods for Special Regimens
XI.7	Impact of the Migration of Components and Residues in Food Packages
XI.8	Obtaining and Characterization of Carbohydrates for Application in Foods for Special Regimens
XI.9	Obtaining and Characterization of Proteins for Application in Foods for Special Regimens
XI.10	Development of Technologies for the Physical Treatment of Quarantine of Tropical and Subtropical Fruits
XI.11	Development of Evaluation Tools for Food Engineering
XI.12	Methods of Prediction of Physical Properties of Foods
XI.13	Structure-properties relation in dehydration and storage of dried foods
XI.14	Development of technologies to reduce diseases in subtropical fruits
XI.15	Development of Emerging Technologies Important for Ibero-America
XI.16	Sensory Shelf-Life in Foods
XI.17	Development of New Compounds of Specific Functionality

Table 2—Thematic networks developed in the CYTED subprogram "Food Treatment and Conservation"

Network nr	Network Name
XI.A	Post-Harvest Technology of Fruits and Vegetables
XI.B	Physical Properties of Foods Relevant to Industrial Design
XI.C	Foods for Special Regimens
XI.D	Food Engineering of Foods for the Development of the Regional Industry
XI.E	Food Packaging
XI.F	Sensory Properties of Foods
XI.G	Nutritional and Toxicology Evaluation of Foods
XI.H	Sanitary Quality Foods
XI.I	Fish Products Technologies

ings, seminars, and other activities in the region. Also in this period, topics like measurement and prediction of a_w, microbial ecology, structural changes of foods during processing, and micro and macroscopic analysis of processes like osmotic dehydration were incorporated as important components of academic programs.

Project XI.3 was conducted from 1995 to 1998 to generate basic knowledge on the effect of diverse preservation factors on microflora, sensory, physical, chemical, and structural properties, and the development of minimal preservation technologies for obtaining fresh, shelf-stable, high-moisture foods. Again, the Argentine groups coordinated the work of all the countries participating in the project. The project also explored the application of minimal processing to preserve freshness of conventional foods, like marmalades. Modified atmospheres, cold storage, a_w reduction, pH control, use of antibrowning preservatives and antimicrobials, edible films, nonthermal physical processes, mild thermal treatments, and vacuum impregnation were among the technologies studied.

Projects 5, 11, and 12, among others, had a special impact on FE development in the region. Project XI.5, called "Effect of the Conditions of Process and Storage on the Physical Properties of Foods," had as objective to standardize and implement methodologies for evaluating physical properties of foods—including thermal, electric, mechanical, mass transport, rheological, and surface properties, and thermodynamic equilibrium characteristics—as a function of composition and structure, and to determine the relationship between these properties and overall food quality. Another important objective was to improve the means for determining relevant food properties, food structure, and food composition as a function of processing, as well as of time and conditions of storage, in order to enhance industrial processes by using physical properties as quality parameters. The leadership of the Chilean groups was very important for the development of this project.

"Development of Evaluation Tools for Food Engineering," Project XI.11, directly relates to the development of human resources in the region. The need for knowledgeable professionals became more evident during the project. Most countries of the region lack of financial resources to obtain the costly facilities and equipment needed to effectively teach FE, as well as to provide research assistance for industry. However, this problem could be addressed with solutions that have already demonstrated their efficacy and viability, such as software that can simulate operations and processes.

Project XI.11 drew participants from Argentina, Brazil, Chile, Cuba, Spain, Mexico, and Portugal. To date, it has offered 9 workshops on computational tools and has distributed publications with free software. More than 90 simulation programs can be accessed at http://www.upv.es/dtalim/herraweb.htm, covering practically all the processes and operations addressed in FE courses. The contribution of the Brazilian and Spanish groups was outstanding in this type of project.

Project XI.12, called "Methods of Prediction of Physical Properties of Foods", also reflects increasing use of computational tools in the design of equipment for simulation and optimization of process operations in the food industry. Groups from Portugal participated in this project supporting the Latin American groups. Models that can predict physical, thermodynamic, and transport properties are needed to develop reliable simulation programs that show how conditions of temperature and pressure (among other variables) can affect process operations. For this reason, the objective of the project was to compile current methods of prediction and development of new methods, and integrate this knowledge into computer programs and databases that can be easily accessed by food engineering students and professionals (Welti-Chanes and others 1999).

Research projects being developed at present time are focused to improve the quality of food products and to better understand their functional properties and components. Project XI.15, called Development of Emerging Technologies Important for Ibero-America, headed by the Instituto de Ciencia y Tecnología de Alimentos from Venezuela, has the approach that the formation of food professionals must have in the future. The general objective of Project XI.15 is to develop selected foods using emerging technologies (high hydrostatic pressures, ultrasound, electric pulses, ionizing radiation) and using other assisting preservation factors.

Table 3—Some publications (books and manuals) released from 1984 to 2001 as products of the CYTED subprogram "Food Treatment and Conservation"

1. Ibero-American Institutions and Topics of Investigation in Food Technology
2. Inventory of Traditional Intermediate Moisture Foods of Ibero-America
3. Methodology for Evaluation of Post-Harvest Losses
4. Ibero-American Directory of Researchers in Post-Harvest of Perishable Foods
5. Memory of the Seminar-Workshop: Link Academia-Private Enterprise in the area of Post-Harvest of Perishable Foods in the Ibero-American Context
6. Summary of Publications on Physical Properties of Foods in the Ibero-American area
7. Ibero-American Survey of Centers of Investigation in Physical Properties of Foods
8. Physical Properties and Thermal Analysis of Foods
9. Rheological Properties of Elaborated Foods in Cuba 1: Fluids
10. Application of Combined Methods in Food Preservation
11. Proceedings of the Conferences of the 2nd Ibero-American Workshop of "New Trends in Plastic Containers for Foods"
12. Project XI.2, Bulk Preservation of Fruits by Combined Methods, CYTED
13. Supplement to the Compendium of Publications on Physical Properties of Foods of the Ibero-American Area
14. ISOPOW International Symposium on the Properties of Water, PRACTICUM II: Food Preservation by Moisture Control
15. Guide of Investigators: Ibero-American Network of Physical Properties of Foods for Industrial Design, RIPFADI
16. Food Engineering 2000
17. Microbial Evaluation by Challenge Testing in Minimal Processed Foods
18. Tools of Calculation in Food Engineering Vols. I, II, III, IV, V, VI, VII, VIII, IX
19. Topics in Food Technology. Vols.1, 2, 3
20. Minimally Processed Fruits and Vegetables. Fundamental Aspects and Applications.
21. Proceedings of the International of Conference on Engineering and Food (ICEF 8), Vols. I, II
22. Engineering and Food for the 21st Century

Table 3 presents some of the publications (books and manuals) that have come out of the Sub-Program's 17-year history. Most of these materials are used as textbooks or mandatory references in FE courses throughout Latin-America. It is important to mention that the CYTED research projects cover most of what are considered "priority topics" for the modern teaching of FE (Singh 1995; Welti-Chanes and Parada-Arias 1997).

In a similar way, as the support of OAS and of UNDP between the 1960s and the 1970s were, and still are, vital for the development of the FE in Latin America, the Sub-Program CYTED XI has been an important generator of information and solutions that have raised the capabilities of Latin-American FE investigators and academics. Consequently, it has raised the possibilities of regional food industries to develop their own technological solutions, adapted to their country's unique conditions, and capable of improving the presence of the country in global markets. However, for less industrialized countries, the role of science, technology, and engineering as instruments of development and performance are still limited. The most important effect of the subprogram is the improvement and strengthening of FE academic programs across Latin-America.

Structure of Food Engineering B.S. (Licenciatura) programs

One hundred and fifty FE programs or related programs were detected in 12 countries of the region. Table 4 presents the distribution of these FE programs by country, Brazil, Mexico and Argentina being those with the greater numbers. The name of the programs change, some of them being Food Engineering, Food Technology, Food Technology Engineering, Chemical Engineering in Food Industries, Food Science and Technology, Chemical Engineering in Foods, Biochemical Engineering, and Food Chemistry. The programs have different structures, but are in general 5-year programs with 150 to 160 (U.S.) credits, and, in most cases, they require a thesis as final project to obtain the degree of Food Engineer.

Figure 1 and 2 present the distribution analysis of the programs in each country according to area of knowledge (in terms of the percentage of credits of each area). Even when most countries are not making efforts to standardize the structure and content of the programs, it gives an idea of the tendencies in structure of the programs. The areas considered for analysis are: Quantitative (Mathematics, Statistics, Numerical Methods, Computation, and Physics), Chemistry and Biology, Chemical Engineering (Thermodynamics, Transport Phenomena, Mass and Energy Balances), Food Science (Food Chemistry, Food Analysis, Food Physical Chemistry, Food Microbiology, Nutrition), Food Processing (Processes and Quality Control), General Requisites (Languages, General Culture, Administration), General Laboratories, Food Laboratories, and Food Engineering.

Several programs have the required number of credits, are oriented to produce sound professionals, and they adequately cover the Core Competencies and the Applied Food Science elements of the Curricular Standards, established by the Institute of Food Technologists (IFT) (IFT 2000). However, it is not easy to decide if they comply with the elements established by IFT that are related with the so-called Success Skills, given the brief analysis presented here.

Table 4—Number of universities with food engineering programs

Country	Number of universities
Brazil	30
Mexico	28
Argentina	18
Chile	9
Peru	7
Colombia	6
Venezuela	5
Bolivia	4
El Salvador	2
Guatemala	1
Nicaragua	1
Uruguay	1

In most cases, the description of the objectives of each program and the graduation profile, together with the structure of the program, indicate that, apparently, the Education Standards requisites established by IFT are complied with, as well as in some programs with those specifically established by Accreditation Board for Engineering and Technology (ABET) as Program Outcomes (ABET 2001).

Although it is difficult to demonstrate with the brief analysis presented here that the ABET and IFT criteria are complied by some programs, the best answer is found in the industries and universities that have or have had professionals of the region working with them or performing Graduate Studies. In most cases, the professional background they have received in their countries of origin has demonstrated that they have been adequately educated and instructed in FE at equal or higher levels than in any other country around the world.

Anyway, the preliminary analysis of the structure and content of the academic programs shows the need to standardize some fundamental elements of the FE academic programs of the region, taking as model the work of IFT or some attempts already in progress in Europe. Also, trying to unify efforts, through the establishment of a work group to define the qualitative and quantitative criteria that every FE program in the world must comply with. It is

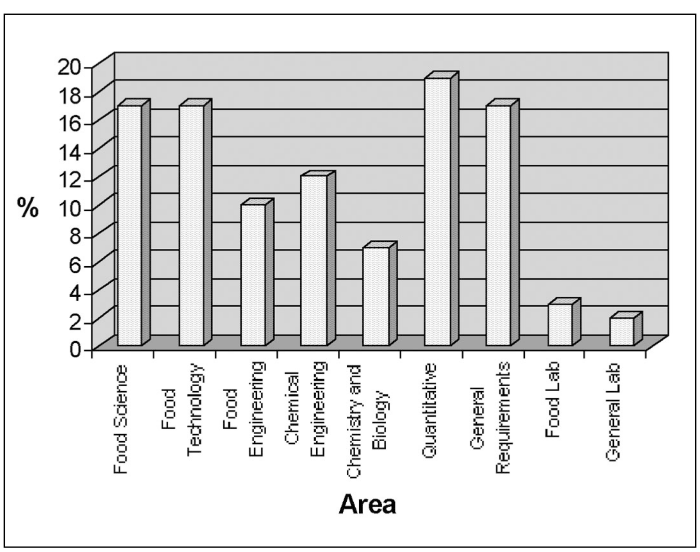

Figure 1—Academic credits distribution of Food Engineering programs according to area of knowledge in Mexico and Central-America.

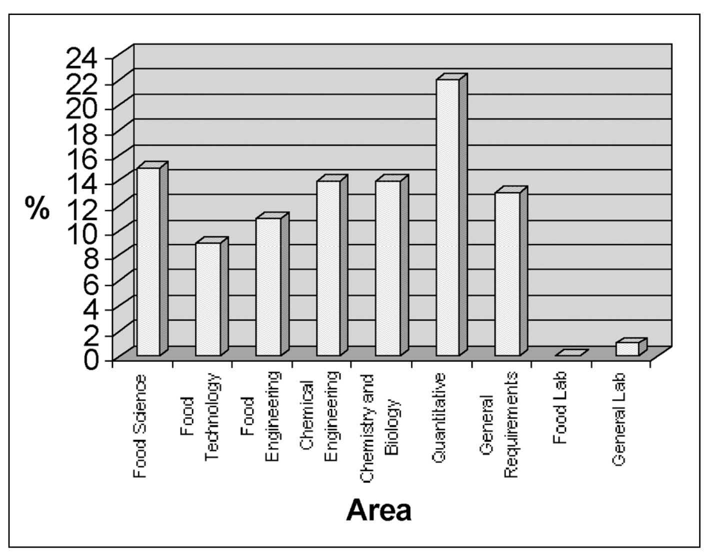

Figure 2—Academic credits distribution of Food Engineering programs according to area of knowledge in South-America.

worthy to mention and to take as a model the Argentine efforts to establish a basic unified criterion for curricular design and the denomination of Graduate through the "Interuniversity Association of the Food Sector" (Asociación Interuniversitaria del Sector Alimentario).

On the other hand, when reviewing the number of students and academic programs of B.S. Food Engineering in the last 5 years it is observed in general (as in the case of Chemical Engineering) a slight tendency to remain equal or slightly reduce the number of programs and students. However, the Master and Ph. D programs present a constant decrease that seems to be related to the growing of Biotechnology Master and Ph. D Programs. FE must take advantage to live together or coexist and include Biotechnology as a priority study area in academic and research programs. In fact, in a study made by Parada-Arias and Ordorica-Vargas (1997), it was demonstrated that, out of 102 Food Science and Technology academic programs evaluated in the region, 45% were strongly related to biotechnology areas such as food biotechnology, environmental biotechnology, and engineering. However, it is important to recognize that in most of the Latin American countries there is a lack of research facilities within the M.S. and Ph.D. programs to adequately serve the students enrolled in the programs related to FE, even when the faculty is adequately prepared from the academic point of view.

Research in Food Science, Technology and Engineering and Its Relation With Academic Programs

One of the best ways to know the orientation of the academic programs is to know the type of research made at the universities that offer such programs. Table 5 presents an analysis of the publications generated from 1998 to present time by researchers that work in universities of Latin-America. The analysis was made based on the information of the journals in which it is considered that the work of researchers from the region is published: *Journal of Food Science*, *Journal of Food Engineering*, *International Journal of Food Science and Technology*, *Journal of Food Process and Preservation*, *Food Science and Technology International*, *Journal of Food Process Engineering*, *Journal of Food Protection*, and *Journal of the Science of Food and Agriculture*.

It can be seen that 4 countries have the greater number of studies published by their researchers (as a function of the size of the country): Argentina, Mexico, Brazil, and Venezuela. The remaining countries practically do not appear, which indicates that their academic programs continue being fundamentally oriented to the transfer of knowledge and not to the creation of knowledge, or that their research work is so specialized that it is published in other type of journals, as can be the case of the research groups of Chile. It can also be observed that several research works are made on Engineering, Processes, and related areas (Transport Phenomena and Physical-Chemistry). It stands out that, according to the type of processes studied, not only traditional processes appear, but there is an important approach to the development of minimally processed foods and use of the so-called emerging technologies. Most of the studies are carried out on fruits and vegetables, which reflects the importance of this type of foods in terms of the regional production.

Table 5—Publications on food science and technology by Latin-Americans.

(1998-2001)		
a. By Country	**Number**	**Percentage (%)**
Argentina	55	34.0
Brazil	27	16.7
Chile	6	3.7
Cuba	4	2.5
Venezuela	19	11.7
Colombia	1	0.5
México	50	30.9
Total	162	100
By area of knowledge	**Number**	**Percentage (%)**
Engineering/Process	41	26.8
Chemistry/Biochemistry	30	19.6
Microbiology	35	23
Nutrition	7	22.3
Physical Chemistry/ Transport Phenomena	34	22.3
Sensory	6	3.7
c. By studied process	**Number**	
Concentration/Drying	31	
Thermal Processing	27	
Minimal Processing	22	
Freezing/Refrigeration	16	
Extraction	11	
Nonthermal Processing	6	
Extrusion	5	
Others	4	
d. By Type of product	**Number**	
Fruits, purees and juices	38	
Cereals	17	
Nuts and grains	15	
Milk Products	12	
Vegetables	10	
Fish Products	9	
Meat Products	8	
Others	13	

Future of FE in the region

It is evident that food science and technology is still an opportunity area to support the development of the region, as are changes occurring in the consumption patterns, food production (transgenic foods for example), way to access information (available technologies for learning), as well as the challenges presented by globalization are also opportunity areas. For these reasons, future actions must be oriented to:

(1) Generate regional work groups to orient the academic programs according to the present tendencies of knowledge, the requirements of the region and criteria internationally established, following an evaluation-certification process like those established by IFT or ABET.

(2) Integrate the work done in other organisms and institutions of other regions of the world to promote a common language in the generation of universally high-quality Food Engineers.

(3) Promote multi-institutional academic programs among different countries, using as model the CYTED's research collaboration, looking for the support of OAS and UNDP, employing advanced communication media to offer courses at distance, and making possible the mobility of students among countries and institutions.

(4) Relate in a greater extent the structure of the academic programs and research, to programs and activities of the food industry of the region, to existing problems due to the marked socio-economic differences, to government policies, and so on.

(5) Use the developments of biotechnology as a support for the advance of FE

(6) Orient the actions of the Food Engineers regarding their academic background and work to the Paradigm for Product/Process Development in the 21st Century (Karel 1997).

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