Food Science and Technology in Developing Countries During the Past 50 Years

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Anniversaries are usually happy occasions, particularly when they commemorate an event which, in one way or the other, is contributing to the well-being of mankind. Anniversaries are also appropriate moments to look back on what has been accomplished, to correct things which may not have turned out as expected, and to plan for the future. Thus, the 50th anniversary of the founding of the Institute of Food Technologists is an appropriate time to review the history of food science and technology in the developing countries.

This topic, however, is difficult to present, since it should discuss and be representative of all the Developing World, which consists of some 95 countries and about 75% of the world population. The content could be presented in a variety of forms, depending on how developing countries are defined and what aspects of the food system are discussed.

Economists define developing countries as countries with a low gross national product (GNP), high underemployment, low income, and poverty; demographers see them as countries with a high annual population growth and high population density; public health officials see them as countries with high infant mortality, disease, and malnutrition; educators see them as countries with a high illiteracy rate; and others see them as countries where food problems are a major concern.

Without an abundant, diverse, safe, and wholesome supply of foods, individuals and entire nations forfeit a life of hope and dignity. But production by itself is not enough; food must be available and accessible to every person in nutritious, safe, and appetizing forms. This means that every consideration must be given to the entire food chain, from production to processing, distribution, consumption, and biological utilization.

The scope of this article is therefore very broad, and it would be difficult to cover advances made in all links of the chain for all developing countries. I apologize for the omissions which I have unwittingly made.

The Supermarket vs the Open Market

The most significant representation of the achievements in the field of food science and technology worldwide in recent years is possibly the supermarket.

For those people not familiar with them, it is simply fascinating to walk aisle after aisle admiring the variety of attractive cartons, cans, and many other fancy containers with all kinds of foods. Aside from the beauty, diversity, and abundance of food items, the supermarket has many implications not evident to the consumer. It implies a very efficient agricultural production, to be used for feeding people and as raw materials for the food industry or other production systems. It implies making seasonal production available throughout the year. It implies many years of research in food science, nutrition, and other allied disciplines. It implies the use of food science research results to develop and implement food technology activities, also the result of research and a close association between research centers and the food industry. It implies the availability of knowledge in packaging, marketing, and quality control. It implies food security and food safety to the consumer. And it implies a receptive population with the knowledge to appreciate the foods, and with the economic capacity to purchase it.

Nevertheless, it is also fascinating to walk through the narrow passages of the colorful open markets typical of developing countries (Fig. 1). There, however, the variety of foods is low, mainly cereal grains and food legumes in burlap bags. Occasionally, baskets full of foods, mainly vegetables and fruits, are also to be found, but their availability is dependent on seasonal production. These foods come from poor and inefficient agricultural production systems, not good enough to supply the demand, deteriorating under the sun, dust, or rain, with flies and other insects as constant visitors. Those foods not sold by the end of the day go to waste. People marketing the foods do not look healthy, and they earn little for their effort because those who purchase do not have sufficient income to purchase more and in a continuous way. Even if they could, the food would be wasted because of the lack of refrigeration and other preservation techniques. Food products such as meat and eggs are in short supply and expensive. Only dry staples are sold, mostly cereal grains. The full benefits of processing, of engineering, and of food science and technology are still not reaching most people in the developing countries. Nevertheless, food science and

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technology has evolved and has contributed to the alleviation of some nutritional problems as well as food needs and to the economies of the countries. Together with other factors, it is also changing the dietary habits of people.

The picture of the open market in the developing country today is very similar to the one which could have been seen 50 years ago. The difference between the two scenes lies only in the greater number of people today. Their appearance, however, is the same—they are malnourished, poor, unhappy persons, and this is more evident in children who go to market with their parents. Between 75 and 80% of a total world population of more than 5 billion live in the developing nations, and their nutritional status definitely is only slightly better than 50 years ago. Because of the significant number of people, low and variable agricultural production, poor economies, low food availability, higher costs, poor-quality foods, and the effects of adverse environments, diseases, and low socioeconomic condition, however, the possibilities for rapid improvement have been very slim.

Obviously, this picture has been the result of many factors acting simultaneously. No one corrective measure by itself will result in the kind of scenario represented by a supermarket. Still, during the past 50 years, food science and technology in developing countries has advanced and made some contributions which could have been more important and effective if other factors had concomitantly existed. It would seem that food science has advanced

much more than food technology, because the first concerns the research laboratory, while the second concerns the application of research results for the benefit of people who for a number of reasons are not ready as yet to take advantage of the outcome of food processing and of food technology as a whole.

A number of problems have taken place in the world, particularly in the developing world, which in one way or another have stimulated the development of food science in the developing countries. But the factors which will stimulate food technology have not yet been attained for all people in the low-economy areas. The factors responsible for the development and increased activity in food science, as well as those which are constraining the faster development of food technology, are discussed below.

Problems Stimulating Food Science and Technology

It is difficult, and even dangerous, to state that events which took place during the past 50 years were solely responsible for the initiation of an interest in developing a capacity for food science and technology in developing countries. With this limitation in mind, several factors can be identified as probably playing a significant role. First is the *malnutrition problem* affecting all low-income groups but mainly children and pregnant and lactating women. Although at first it was felt to be a medical problem, it soon became apparent that *quality and quantity of food* were important. While efforts were beginning to be made to increase food production, it was felt that availability of what was produced could be increased by activities in *postharvest technology*. On the other hand, great losses of grains and of many other foods were recorded, and much interest developed to find ways to reduce such losses through simple but effective technologies.

Nevertheless, nutrition and food problems were not the only events which stimulated the development of food science and technology. Others include the need to produce and preserve more foods required by an *increasing world population*. Likewise, for some time now, all developing countries have been experiencing a *migration of people from rural to urban areas*. The *economies of developing countries* have reached such low levels that they have made it essential for their survival to process foods which before were imported.

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On the other hand, the relatively high capacity to produce agroindustrial crops such as sugarcane and oilseeds led to the development of sugar and oil extraction and refining industries, to meet specific needs for sugar and oil and oil-based food products. Realization also came that in the developing countries problems such as those listed could be solved by strengthening local *human resources*, in spite of the fact that much help came from the developed

Fig. 1—Typical Open Market in Guatemala

world. In addition, much if not all of the technologies being utilized came from countries with knowledge and information. It was and is felt that *knowledge and information* must be produced locally to effectively develop food science and technology in developing countries.

It is of interest to point out at this time that the Institute of Food Technologists and the League for International Food Education (LIFE) conducted a study in Latin America in 1976 to identify actions which might be taken by governments of developing countries and donor agencies to stimulate the application of local food technology resources to the solution of malnutrition problems in Latin America (Buchanan and Stewart, 1977).

The study found a wide range of food technological resources in Latin America, from very good and modern to very poor and primitive. The authors also found that malnutrition conditions among the population were relatively similar throughout Latin America. They recognized that the conditions were more serious in the fringe areas of large cities caused by the influx of poor people from rural areas, and that many other factors were responsible, such as illiteracy, food habits, low income, poor communication, inadequate processing, handling, storage, and distribution technologies, poor water supplies, ineffective and/or inadequate government nutritional policies, disease, and inadequate agricultural production. They reported serious postharvest losses and identified a number of constraints which hindered food technology resources from being more effectively used in contributing to the solution of the problem.

● **The Malnutrition Problem.** Some 50 years ago, evidence was being obtained on the nutritional status of people in the underdeveloped world. Some factors associated with this malnutrition problem that gave rise to food science and technology were protein/calorie malnutrition; specific nutritional deficiencies such as iodine, iron, and vitamin A; lack of information on nutrient intake from local food consumption during pregnancy and lactation; nutritional problems during the weaning process; diarrhea; and infection. The relation of some of these factors to the development of food science and technology is shown in Table 1.

The nutritional deficiencies known as marasmus and kwashiorkor, however, attracted the attention of medical scientists, who concluded that the former was due to low intakes of both good-quality protein and calories, while the latter was due to a deficiency in the intake of good-quality protein accompanied by deficiencies of other nutrients.

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However, between these two extremes, a great many children suffered from some degree of malnutrition (Scrimshaw and Behar, 1961). This problem gave rise to two important activities involving food science. The first was related to obtaining information on the nutrient composition of foods, and the second to the search for vegetable proteins which could provide a good balance of essential amino acids, since animal food products were too high in cost and not readily available. Other resources such as fish protein concentrate and single-cell protein became better known.

Knowledge of food composition was almost mandatory in order to understand and interpret food intake data and nutritional adequacy. Thus, many native foods were analyzed, and the information was published as early as 1943 in a number of scientific journals, one of them being *Food Research*, now known as IFT's *Journal of Food Science*. The data from a relatively great number of researchers were finally compiled into food composition tables, which led to the appearance of a table for Latin America in 1961 (INCAP-ICNND, 1961). Similar information for Asia also became known in the early 1950s (Rand et al., 1984) and possibly for Africa as well. The data published in scientific journals and in tables served a useful purpose. However, it is necessary for food composition tables to be upgraded in quality of the analytical data, in quantity of foods, and in nutrients, since many changes in food production, storage, and processing known to affect composition, as well as changes in analytical techniques, have taken place over the years.

With regard to the search for products containing good-quality protein, significant amounts of research were carried out on local resources. Knowledge was thus obtained on a number of oilseeds such as sesame in Mexico and peanuts in India (CFTRI, 1974; Parpia and Subramanian, 1966), cottonseed in Central America and Peru (Bressani et al., 1966), and soybeans in Asia (CFTRI, 1974; Parpia and Subramanian, 1966). Oilseed flours from such products were developed and incorporated into mixtures with cereal grains, giving rise to products known as high-quality foods. Simultaneously, these foods were tested in human subjects with relatively good results, which encouraged their industrial production. Products such as *Multipurpose Food* and *Bhal Ahar* in India, *Incaparina* in Central America (Fig. 2), *Maisoy* in Bolivia, *Protina*, made from Incaparina and Maisoy (Fig. 3), *Faffa* in Ethiopia, *Superamine* in Algeria, *Laubina* in Lebanon, and many others were produced (Bressani and Elias, 1973). Quite often, little life expectancy was given to them, but many have survived. Furthermore, food industries to produce such foods were developed, setting in motion other activities such as processing and refining of basic ingredients, acquisition of modern technologies such as extrusion cooking, development of human resources to run the industries, and establishment of the quality control laboratory.

All of these developments yielded significant amounts of scientific information. This information has served a useful purpose and built a base for the research now being conducted. Interestingly enough, the search for high-quality food proteins still occupies the time and effort of scientists all over the world, including the developing countries. The search for solutions has continued. The development of fish protein concentrate, to be used as a supplement, was a significant contribution. Other kinds of fortification of foods were studied, and some implemented; the best example probably is the addition of iodine to salt.

The lack of implementation of food research findings is one of the more disturbing factors which somehow must be solved.

The difficulties in solving malnutrition gave rise to the recognition that it was a problem which needed the efforts of a number of disciplines not commonly found in developing countries. It also strongly indicated that agriculture had a role to play in increasing production of the basic staples, and that food science and technology also had a significant role to play. Thus, during the early days of 1960, action was started in this direction.

● **The Food Problem.** Significant amounts of research on the causes and consequences of malnutrition were being conducted in the 1950s, when it was realized that foods, particularly the basic staples, were not being produced in sufficient quantities; therefore, their availability was also low, particularly for people with poor economic resources. As a result, a number of activities were proposed, some of which are increase in agricultural production; reduction of postharvest losses; reduction of wheat imports; development of the composite flour concept; development of

Table 1—**Malnutrition Problems** and the application of food science and technology in developing countries

Malnutrition problem	Food science and technology research	Output
Protein/calorie malnutrition	Vegetable proteins, fish protein concentrate, single-cell protein	High-nutritive-value foods
Poor nutritional status of people and low nutrient intake	Food analysis	Food composition tables
Iodine deficiency	Potassium iodate addition	Iodized salt
Vitamin A deficiency	Vitamin A stability in sugar	Fortified sugar
Iron deficiency	Heme iron from animal blood	Fortified bakery products
Low food intake in children	Increasing caloric density	Partially hydrolyzed food products

autochthonous technologies; reduction of seasonal variation in food availability; introduction of the grain quality concept; food quality improvement through fortification, supplementation, and complementation; development of new sources of foods; and demand for specific food items, such as oils.

The low agricultural production of basic staple foods prompted the establishment of the International Agricultural Research Centers in developing countries in Asia, Africa, and Latin America. An event which was fundamental in their recognition was the Green Revolution, and undoubtedly they have made significant contributions in increasing food production worldwide. Soon, these institutions, besides increasing production, introduced into their objectives concepts in the area of food science, particularly grain quality characteristics of the staples and other foods of their particular mandate. The institutions also promoted food and utilization research activities; e.g., research by the International Rice Research Institute on rice (IRRI, 1979); research by Centro Internacional de Agricultura Tropical (CIAT) on use of cassava as a substrate in biotechnology (Cook et al., 1976); and research by the International Potato Center (IPC) on potatoes as a component in high-quality foods (Valle-Riestra, 1984). Food legumes also came into focus as potential sources of complementary protein; this not only induced increased research efforts for these foods, but also stimulated the agricultural sectors, national and international, to increase their production and utilization in food product development.

The malnutrition problem was also responsible for the finding that it was possible to select cereal grains of better nutritional quality; the classical example was opaque-2 corn, now known as quality protein maize, QPM (Anonymous, 1972). Likewise, triticale was developed and became famous, on the one hand because it was manmade and on the other because it has a higher content of high-quality protein than other cereal grains (Hulse and Laing, 1974). Other higher-quality cereal grains were found, such as high-lysine sorghum and *Hiproly*. Many studies were conducted on cereal grain supplementation with amino acids and/or small amounts of protein of both vegetable and animal origin (Scrimshaw and Altschul, 1969). Food complementation studies were also published, showing the significant improvement attained when two food sources mutually supplied each other's deficiencies, resulting in a product of better nutritional quality than either component alone (Bressani, 1974a). All of these solutions were solid in terms of their potential nutritional benefits; nevertheless, it is difficult to cite examples of their technological application in the developing countries.

Fig. 2—**Incaparina,** one of the high-quality products resulting from research on local resources in Central America

Fig. 3.—**Protina,** another high-quality food, prepared from Incaparina and Maisoy

The malnutrition problem also influenced other areas of food science research. One of the best examples is the study of the lime-cooking process for corn to make tortillas. The technology, as described in the early 1950s with all the chemical data supporting it (Bressani et al., 1958; Bressani and Scrimshaw, 1958), has been very well used in the developed world, particularly in the United States. Likewise, chappaties made in India were extensively studied, as were other autochthonous technologies, like those used in Asia to process soybean (Steinkraus et al., 1983). The need to improve the biological utilization of local grains promoted research in understanding of the native processes to convert them into edible products. An interesting example is the many ways African populations developed to utilize sorghum and millet (Olatunji et al., 1982). Other achievements, such as leaf protein concentrate, were attained, not necessarily in developing countries (Pirie, 1971). Nevertheless, leaf protein concentrate is a resource not yet extensively utilized.

Research carried out in developing countries on various aspects of the food system brought into the news and research areas the problem of developing postharvest technology, particularly to reduce losses of staple foods. Thus, the grain storage practices as conducted in developing countries were analyzed, and solutions to the problems found were provided and implemented to reduce food losses as much as possible (BOSTID, 1978). The problem of postharvest food losses still prevails, particularly with small farmers, who to a very large extent are responsible for the production of the basic staple foods.

A problem now receiving worldwide attention is the hard-to-cook condition in beans, which has not as yet been resolved (Vindiola et al., 1986). This condition induces difficulties in cooking beans, causing large expenditures in energy and, as a consequence of the prolonged cooking times, losses in nutritive value and acceptability to consumers. This problem is useful to indicate that, besides nutritive value, other attributes of the different commodities are also being recognized, such as functionality characteristics.

A relatively high number of surveys of foods consumed

in developing countries indicated that wheat, as wheat flour, was being consumed in increasing quantities. Since most developing countries located in the tropical belt of the world do not produce wheat, which must therefore be imported, the composite flour concept was born (Kim and de Ruiter, 1969). It received much publicity and research efforts in the early 1970s Cassava flour became better known as a product useful with wheat flour to make bread. Although much was done in the developing world, very little of that was placed into actual use. When wheat economics became lower in comparison with costs of locally produced grains, the program on composite flours lost interest. However, it is still very important and probably much more significant today because of the developing countries' poor economic situation and increasing population.

The food problem not only had to do with low quantity and availability but also with the quality, particularly that of protein; this induced food research on cereal grains in particular. Many studies were conducted showing the nutritional limitations of cereal grains; and many studies showed how they could be improved by a large number of supplementary foods. In all cases, the results were outstanding, and technologies were proposed. But, after so much good research, none, or very few, of those results have been implemented. The lack of implementation of food research findings is one of the more disturbing factors which somehow must be solved.

● **The Population Problem.** Significant changes in the quantity and quality of the human population have taken place in the developing countries during the past 50 years (IADB, 1987) years and will continue to take place. There is still a significant increase in the number of inhabitants of the developing world, and this will induce a higher demand for food. However, a problem which is possibly as serious is the change in the quality of the population. As Tables 2 and 3 show, while the developing countries had a greater number of people in the rural areas early in 1960, today urban populations are increasing at a very high rate. In all countries of Latin America, the number of people migrating to cities is greater than the number of people living in the rural areas. The change in quality also is evident in the development of a higher middle class, which, with a higher income and greater knowledge, is beginning to demand or be able to purchase better-quality foods. Convenience foods, which may be the factor missing in the application of the food science research conducted in previous years, may be the catalyst to implement the technologies in the food industry. Surveys conducted in the capital cities of most developing countries show a significant increase in street sale of ready-to-eat foods (Bressani et al., 1986).

The increase in total population, in urban population, and in the middle class is also influencing young people to obtain a higher education in areas other than law, medicine, and conventional engineering. This, together with

Table 2—**Change in Total and Urban Population** in selected Latin American countries from 1960 to 1986. From IADB (1987)

	1960		1986	
Country	Total population (1,000)	% urban	Total population (1,000)	% urban
Bolivia	3,294	26.9	6,611	47.7
Colombia	15,557	48.0	29,058	66.6
Costa Rica	1,320	31.1	2,530	49.5
Ecuador	4,429	34.2	9,647	52.7
Honduras	1,988	22.0	4,514	40.4
Mexico	37,073	50.8	79,504	69.7
Peru	10,385	44.6	20,208	67.7
Venezuela	7,963	64.1	17,914	81.3

Table 3—**Some Population Statistics** in Latin American countries in 1987. From BID (1987)

Country	Annual growth rate (%)	Urban population (%)	Life expectancy (years)
Argentina	1.6	84.7[a]	69.7
Bolivia	2.8	47.7	50.7
Brazil	2.5	74.5	60.5
Colombia	1.6	66.6	62.1
Costa Rica	2.6	49.5	73.1
Chile	1.7	84.0	70.9
Ecuador	3.1	52.7	65.4
El Salvador	2.1	41.8	63.3
Guatemala	2.8	32.7	62.0
Honduras	3.2	40.4	62.0
Jamaica	1.5	48.4	70.3
Mexico	2.7	69.7	66.1
Nicaragua	3.4	56.9	59.8
Panama	2.2	51.5	72.1
Paraguay	3.2	43.9	68.0
Peru	2.6	67.7	60.8
Dominican Republic	2.4	53.3	64.1
Trinidad and Tobago	1.4	85.0	70.3
Uruguay	0.5	85.0	70.3
Venezuela	2.9	81.3	69.0

[a]E.g., 84.7% of the total population in Argentina live in urban areas

Table 4—**Factors Within the Economic Problems** in developing countries which contribute to the development of food science and technology

Problem	Corrective action needed
Poor economic condition of country	Develop agroindustries to decrease food imports; increase food availability; introduce processing to obtain added value of raw materials
Low-income population	Introduce locally processed foods; develop local industry
Underemployment	Increase employment
High cost of foreign technology	Develop applied research institutes in food and other industries
Needs and problems of local food industry	

the agricultural and economic problem within countries plus the lack of job opportunities in law and medicine or pharmacy, has stimulated the development of new professional disciplines, including food science, technology, and engineering. This is slowly creating a critical mass which, together with the needs of the industry and those of the countries, will result in developments of food technology in the developing world.

On the other hand, the food industry is beginning to contribute to development by, among other things, increasing food production and productivity of some agricultural crops, decreasing food losses, increasing food availability, reducing seasonality, providing employment and a higher income, making available high-nutritive-value foods, and, in general, increasing the economic situation. Marketing strategies are beginning to include nutrition information on the label, which together with nutrition education programs, is making the population aware of nutritional quality and safety. However, the limiting factor at present is the relatively small population with the economic means to purchase processed foods.

- **The Economic Problem.** Developing countries have always had economic problems of one kind or the other. They always sold by the kilogram at low prices, and bought by the pound at high prices. In addition, in recent years, the devaluation of the local currency and the low prices of the commodities produced in the developing countries have resulted in even greater economic problems than in the past. This situation—negative in nature—is in fact resulting in a positive measure in a number of areas, including food science and technology. The problem and actions being taken are shown in Table 4.

To decrease imports, create jobs, obtain added value, and increase food availability and variety throughout the years, food agroindustries are being created, particularly in the rural areas, with small producers and cooperatives (Bressani, 1974b; CITA-RETADAR, 1985). Although the development of such agroindustries is not an easy task, it is bringing into view such things as the need to consider them as systems with three main components—agricultural production, processing, and marketing; the quantity and quality of materials to be processed; the kind of technology to use; the quality of the product; the marketing and management problems; and the social quality of the people being benefitted. It may be safely stated that the technology to be used presents the least of the problems; in fact, the quantity and quality of raw materials, as well as of people, and marketing represent the most important constraints.

- **The Human Resources Problem.** Early in the past 50 years, the problems already discussed in general terms and in a qualitative manner pointed out a great deficiency in the developing world: the urgent need to develop human resources in all areas of the food system. It was felt that the problems in the developing countries could be solved by training local scientists to find local solutions. This need gave way to a program for training in the industrialized countries. Although it is far from meeting the needs, it has—together with a diversity of communications, congresses, foreign teams visiting developing countries, and postgraduate training—been creating the critical mass of scientists needed in the different areas of food science, technology, and engineering to put in motion the kind of

Table 5—**No. of Institutions** in some Latin American countries conducting food science and technology research in 1976. From de-Visscher (1976)

Country	No.
Argentina	21
Bolivia	5
Brazil	26
Chile	19
Colombia	9
Dominican Republic	1
Ecuador	5
Guatemala	4
Jamaica	1
Nicaragua	2
Paraguay	3
Peru	7
Uruguay	9
Venezuela	6

Table 6—**No. of Articles on Food Science and Technology** published in selected journals by scientists from developing countries

Journal	Year	Articles			No. of countries
		Total No.	No. from developing countries	% from developing countries	
Journal of the Science of Food and Agriculture (United Kingdom)	1960	131	11	8.4	2
	1973	94	18	19.1	4
	1986	154	31	20.1	12
Journal of Food Science (United States)	1961	114	6	5.3	2
	1974	322	15	4.6	8
	1985	454	51	11.2	13
Archivos Latinoamericanos de Nutrición (Latin America)	1966	12	3	25.0	—
	1976	23	11	47.8	—
	1985	49	30	61.2	—
	1986	54	19	35.2	—

activity required to solve a number of the problems which still remain.

As a consequence, a number of events have taken place. First, local universities have started building up academic programs to award professional degrees in food science and technology. Governments have created special institutes to undertake developmental and adaptive food research to serve the food industry, and have created laboratories for quality control with trained personnel. And institutes in nutritional sciences have incorporated into their structure technical groups in food science and technology to work on food problems with a nutritional content not greatly appreciated by the conventional food industry or government food research institutes.

The problem, at least in certain countries in the developing world, is that the conventional food industry has not responded as yet in employing the professionals in food science and technology who are graduating. Table 5 summarizes the number of institutions in Latin America involved in food science and technology in 1976 (de Visscher, 1976). The number was relatively large at the time and has probably increased since then. The variety of research topics which were being conducted, as described by de Visscher, was impressive, suggesting a high interest in developing food science and technology in the area.

Second, local students trained in industrial countries have, upon returning to their own country, been organizing food science and technology associations which are helping create this very much needed discipline. Examples are Asociación Latino Americana de Tecnología de Alimentos, founded in Brazil in 1982; Asociación Argentina de Tecnólogos Alimentarios, founded in 1968; Sociedad Chilena de Tecnología de Alimentos, founded in 1972; Asociación de Tecnólogos en Alimentos de México, founded in 1970; and Asociación de Tecnólogos de Alimentos de Guatemala, founded in 1987. Furthermore, these societies as well as other groups publish their scientific findings in a number of technical journals, including *Alimentos* (Chile), *La Alimentación Latino Americana* (Argentina), *Industria Alimentaria* (Brazil), *Boletín do Instituto de Technologia de Alimentos*, (ITAL, Brazil), *Archivos Latinoamericanos de Nutrición*, published by INCAP (Guatemala); *Tecnología de Alimentos* (Mexico); and *Tecnología*, published by Instituto de Investigaciones Tecnológicas (Colombia). The information published is quite variable, ranging from descriptions of plant equipment to research articles, some of which are of a quality which would be acceptable in international scientific journals.

Food science and technology is increasing in the developing countries, and it is certainly expected that this trend will continue in the future. The important activity now and in the future is the transfer of the great many research findings into practical application.

It is difficult to obtain statistics on the number of trained people in food science and technology in developing countries, and more difficult to indicate that the discipline is, in fact, advancing. An indicator, however, could be given by the number of articles now being published by food scientists from developing countries in internationally recognized, refereed scientific journals. Accepting that this analysis is not really representative, I screened three journals for papers in food science published by food scientists from developing countries; the results are shown in Table 6. Of the articles published from 1960 to 1986 in the *Journal of the Science of Food and Agriculture*, published in the United Kingdom, 8.4–20.1% were from developing countries, and the number of countries increased from 2 in 1960 to 12 in 1986. For the *Journal of Food Science*, published in the U.S., 5.3% of the papers were from two developing countries in 1961, while 11.2% were from 13 developing countries in 1985. The third journal surveyed is the *Archivos Latinoamericanos de Nutrición*, selected to show that 25–61% of the papers are

Efforts which were initiated some 50 years ago must be increased substantially if the developing countries are ever to have supermarkets with the quantity, quality, and variety of foods that exist in the industrialized countries.

Table 7—**Structure of the Mexican Food Agroindustries in 1976.** From DGE (1979)

Item	Total	Percentage of total by size of industry				
		Artisanal	Small	Medium	Large	Very large
Establishments	57,703	66.9	31.1	1.6	0.3	0.1
Employees	373,525	18.5	23.1	26.5	17.7	14.2
Salaries	12,756,115 pesos	1.3	12.3	30.8	28.4	27.2
Added value	34,654,144 pesos	2.2	11.3	24.1	23.1	38.7
Investment	30,470,861 pesos	2.6	9.5	29.7	29.2	29.0
Total production	109,814,760 pesos	1.6	11.1	25.8	25.6	35.9
Gross capital investment	3,933,000 pesos	2.4	10.0	27.7	39.1	20.8

in the area of food science and technology, mainly from Latin America.

All these facts taken together suggest that food science and technology is increasing in the developing countries, and it is certainly expected that this trend will continue in the future. The important activity now and in the future is the transfer of the great many research findings into practical application.

Table 8—**Development of the Food Industry in Venezuela.** From Morales Carroz (1987)

Classification	No. of establishments		No. of employees	
	1971	1984	1971	1984
Meat processing	42	90	3,655	8,774
Milk products	95	108	4,579	8,291
Canned fruits and vegetables	44	46	2,310	5,465
Fish products	16	14	3,170	3,228
Fats and oils	12	18	3,714	3,226
Grain milling	81	111	4,158	6,854
Bakeries	1,091	1,718	13,550	22,350
Sugar	44	28	4,804	5,619
Chocolate and candy	37	40	2,345	5,220
Diverse food products	131	160	3,247	4,096
Feeds and concentrates	17	44	1,333	3,175
Spirits	53	44	1,743	2,586
Wine	6	3	172	260
Beer	8	7	3,013	5,416
Nonalcoholic beverages	75	73	4,195	6,352

The Food Industry in the Developing Countries

Because of the difficult task involved in presenting a view of the food industry in the developing world, information will be provided only for Latin America, assuming that something similar has taken place in other countries of the Third World. Throughout this article, I have stated a number of times that in the majority of the developing nations, relatively high amounts of research in food science at the laboratory level have been carried out during the past 50 years but very little of it has been used in food technology, and much less implemented. Part of the answer to this problem may become evident in the statements made in this section of this article, which may explain the lack of interest by small- and medium-sized national food industries, as well as the large national and multinational food industries, in local food science and technology research.

The LIFE–IFT Nutrition–Food Technology Study (Buchanan and Stewart, 1977) found 17 constraints which have prevented the food technologists and food technology institutions from using their resources more effectively in Latin America. The authors also suggested 25 ways in which food technology resources could be used more effectively to increase food availability.

At present in Latin America, there are five broad categories of food industries—the primitive (artisanal), the small, the medium, the large, and the very large; these are illustrated for Mexico in Table 7 (Anonymous, 1979). The food industry is, therefore, highly heterogeneous, exhibiting great diversity in the size of the establishment, the technology employed, the quality of the products, and other related factors. As shown, the primitive and small units represent the majority of the establishments and absorb the greatest proportion of the labor force; however, they have a low productivity of the invested capital and represent a low proportion of the total production. Obvi-

Table 9—**Development of the Food Industry in Peru.** From Lajo Lazo (1986)

Classification	No. of establishments		No. of employees	
	1976	1980	1976	1980
Meat processing	33	38	864	1,067
Milk products	52	78	3,868	3,102
Fruits and vegetables	36	66	1,642	2,497
Fats and oils	42	40	2,436	2,352
Grain milling	164	199	3,963	4,275
Bakeries	875	905	12,033	12,497
Sugar	37	43	6,480	5,628
Chocolate	53	84	2,848	3,017
Diverse foods	191	243	3,726	3,799
Feed and concentrates	28	38	1,333	1,786
Spirit beverages (distilled)	104	248	1,827	2,398
Wine	81	99	1,069	1,214
Beer	11	12	3,570	5,970
Nonalcoholic beverages	122	141	4,498	4,405
Alcoholic beverages	13	13	3,057	3,038

Table 10—**Possible Reasons for the Lack of Interest of the Food Industry** in developing countries in using local food science and technology research findings

Multinational industry
- No credibility of national research results
- Lack of competence in the market
- Small markets and revenues
- Products being marketed have been patterned by food industry in developed countries
- No interest in developing or marketing foods to meet local food habits
- Strong control by head office in developed country

Small and medium-size industries
- Little or no communication between food science and technology centers with the food industry
- Lack of understanding and common interests between research groups and industrial personnel
- Lack of government stimulus to industry for the utilization of national technology
- Difficulties in supporting research costs in food science and technology
- Research results not related to industry problems
- Small earnings

ously, these enterprises do not absorb food science and technology professionals nor utilize local research findings; but much could be learned from them, and much could be done to optimize their production.

In Latin America, the food industry represents a high percentage of all industrial activity. For example, in Central America in 1968, the food processing industry accounted for 30.6% of industrial establishments, 24.8% of the industrial labor force, 25.3% of the value added by industry to the region, and 35.9% of the value of the fixed capital investment for five countries (FAO, 1972).

The food industry in Latin America is evolving slowly. Some industries are progressing more than others, not only within a given country, but also between countries. Data for Venezuela are presented as an example in Table 8. The meat processing, milling, and baking industries have shown significant increases from 1971 to 1984 (Morales Carroz, 1987). Data for Peru are shown in Table 9, with trends very similar to those shown for Venezuela (Lajo Lazo, 1986). Data from various countries reveal that two industries increasing in size and number are grain milling and baking. One of the best examples is the development of the lime-cooking process applied to maize to produce tortillas. The native technology as practiced by Mayan and Aztec civilizations in the past, and even today (Figs. 4 and 5), has been developed into small industries (Figs. 6–8) and even highly sophisticated tortilla flour industries in some countries in Latin America, as well as in the U.S. The same can be indicated for arepa flour in Colombia and Venezuela (Rooney and Serna-Saldivar, 1987).

—*Continued on page 130*

Fig. 4—**Washing of Maize** after lime cooking for traditional tortilla making

Table 11—**Problems Partially Responsible** for the development of food science and technology in developing countries, and actions taken

Constraint	Year	Action
Protein/energy malnutrition	1940	Food analysis Search for high-quality protein sources Iodine fortification of salt
Food availability	1950–60	Increase in agricultural research
	1960	Development of autochthonous processing technologies
	1965	Food quality improvement
	1970	Composite flours
	1976	Reduction of postharvest losses
Population	1960	Increase in food availability Increase in food processing
Economics	1970	Agroindustries
Human resources	1960	Foreign training Development of food science and technology

Fig. 5—**Traditional Preparation** of tortillas in Guatemala

Because of many of the problems referred to above, the role of the food industry in the development of food science and technology is very small, although this may not be the case in all developing countries. It is possible that there are many reasons for this state of events, and that it will change in the future. However, the participation of the food industry would have helped it evolve more rapidly in the developing countries. Some possible reasons for the food industry's lack of interest in promoting national food science and technology research in the developing countries and in using research findings are listed in Table 10 for the multinational food industry and the medium and small food industries. Some of these were identified by the LIFE–IFT Nutrition–Food Technology Study.

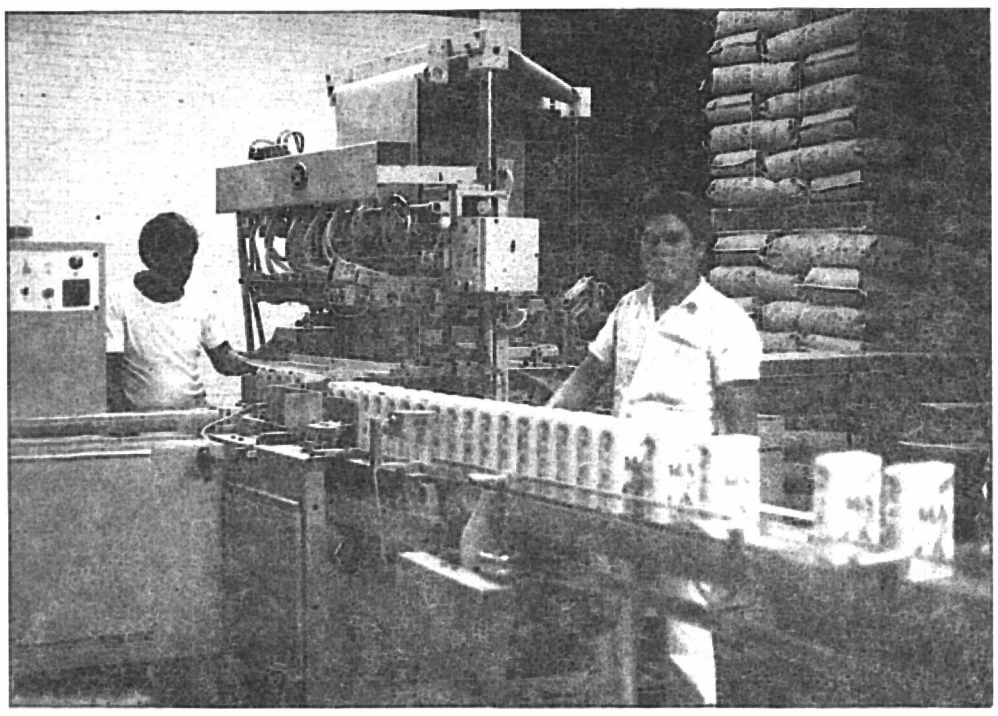
The agricultural production capacity of the countries must be reinforced to be able to develop stronger food industries. In most countries, there is an inability of the agricultural sector to provide the raw materials in the quality and quantity required by the food industry, with the possible exception of conventional agroindustrial crops such as sugarcane. The same may be true for the edible oil industry. All these crops are in the hands of the agricultural sector with a high capacity (economic resources, knowledge) to invest in technology. On the other hand, cereal grains, fruits, and vegetables are in the hands of farmers with a low capacity to invest and to absorb and utilize technology; this is also the case for the small- and medium-sized industries.

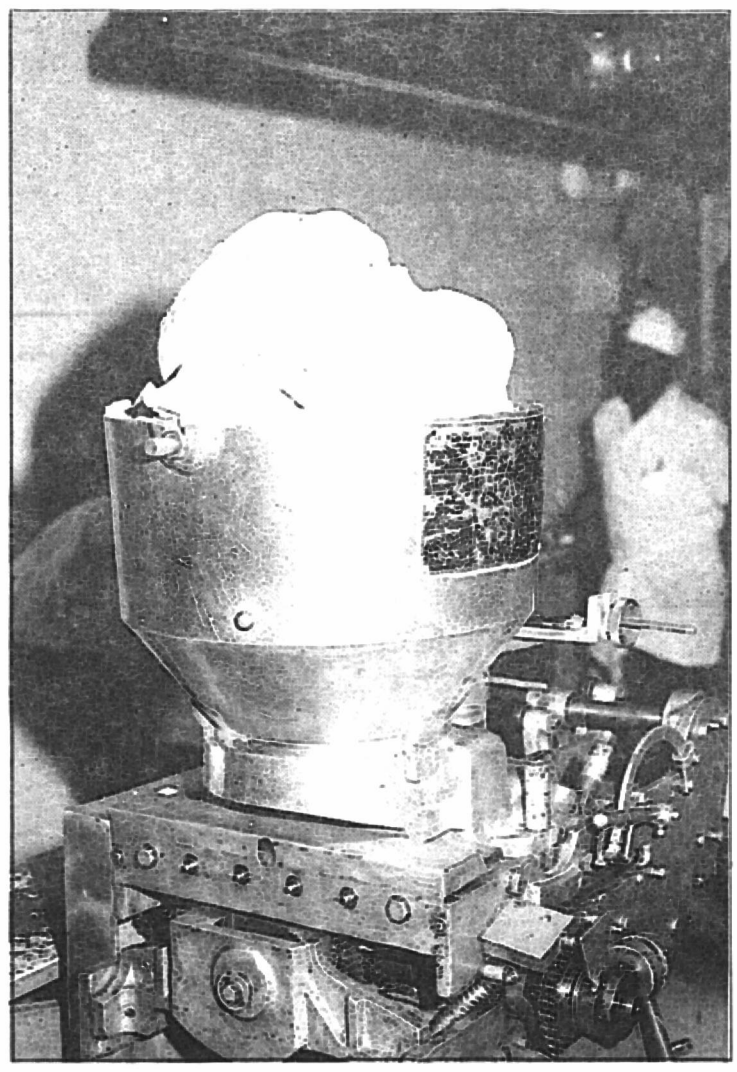
Agricultural productivity by itself will not stimulate the development of the food industry in Third World countries. The distribution and marketing aspects must also be increased. . . .

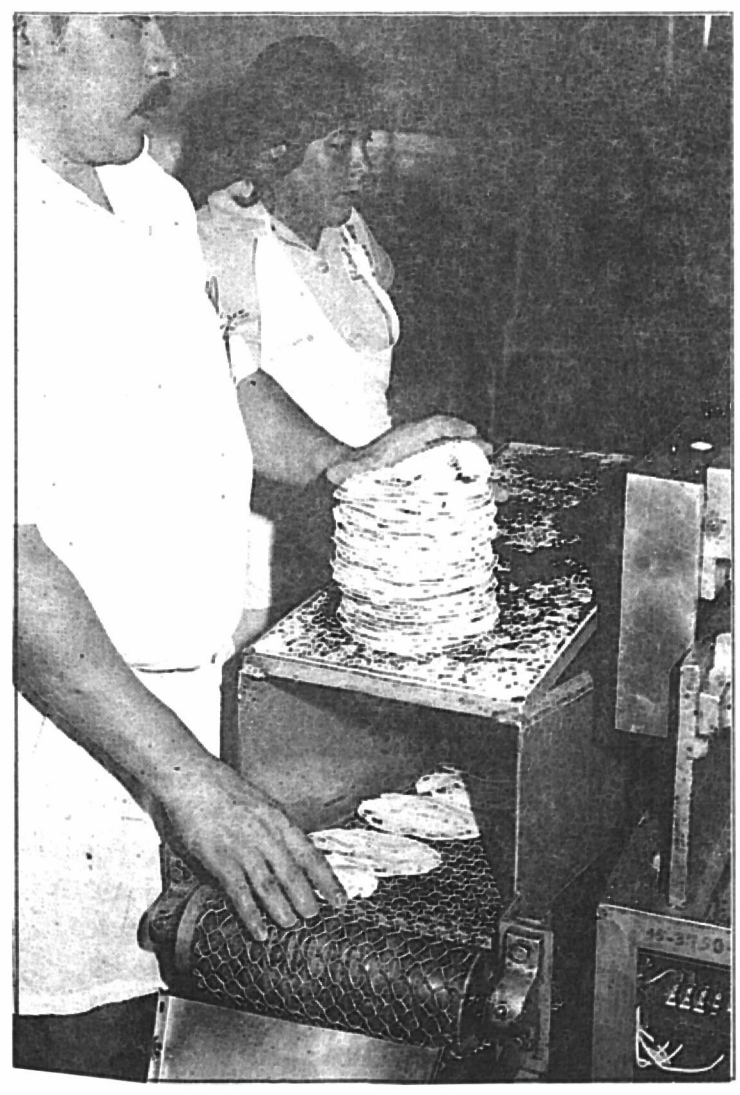
But agricultural productivity by itself will not stimulate the development of the food industry in Third World countries. The distribution and marketing aspects must also be increased, both internally and for export—internally by increasing the purchasing capacity and socioeconomic condition of the population, and for export by manufacturing products with the high quality standards required by foreign markets.

Efforts Must Be Increased

Figure 9 illustrates the multidisciplinary approach that must be taken to deliver food and nutrition to consumers in the developing countries. With the many problems facing the developing world (Table 11), there is no doubt that food science and technology will have a greater and more responsible role to play in the future. One must bear in mind, however, that efforts which were initiated some 50 years ago must be increased substantially if the developing countries are ever to have supermarkets with the quantity, quality, and variety of foods that exist in the industrialized countries.







Figs. 6-8—**Industrial Tortilla Process in Mexico: Fig. 6 (above)**—Maize flour being packaged; **Fig. 7 (left)**—Dough being prepared from maize flour; **Fig. 8 (right)**—Tortillas being produced by machine

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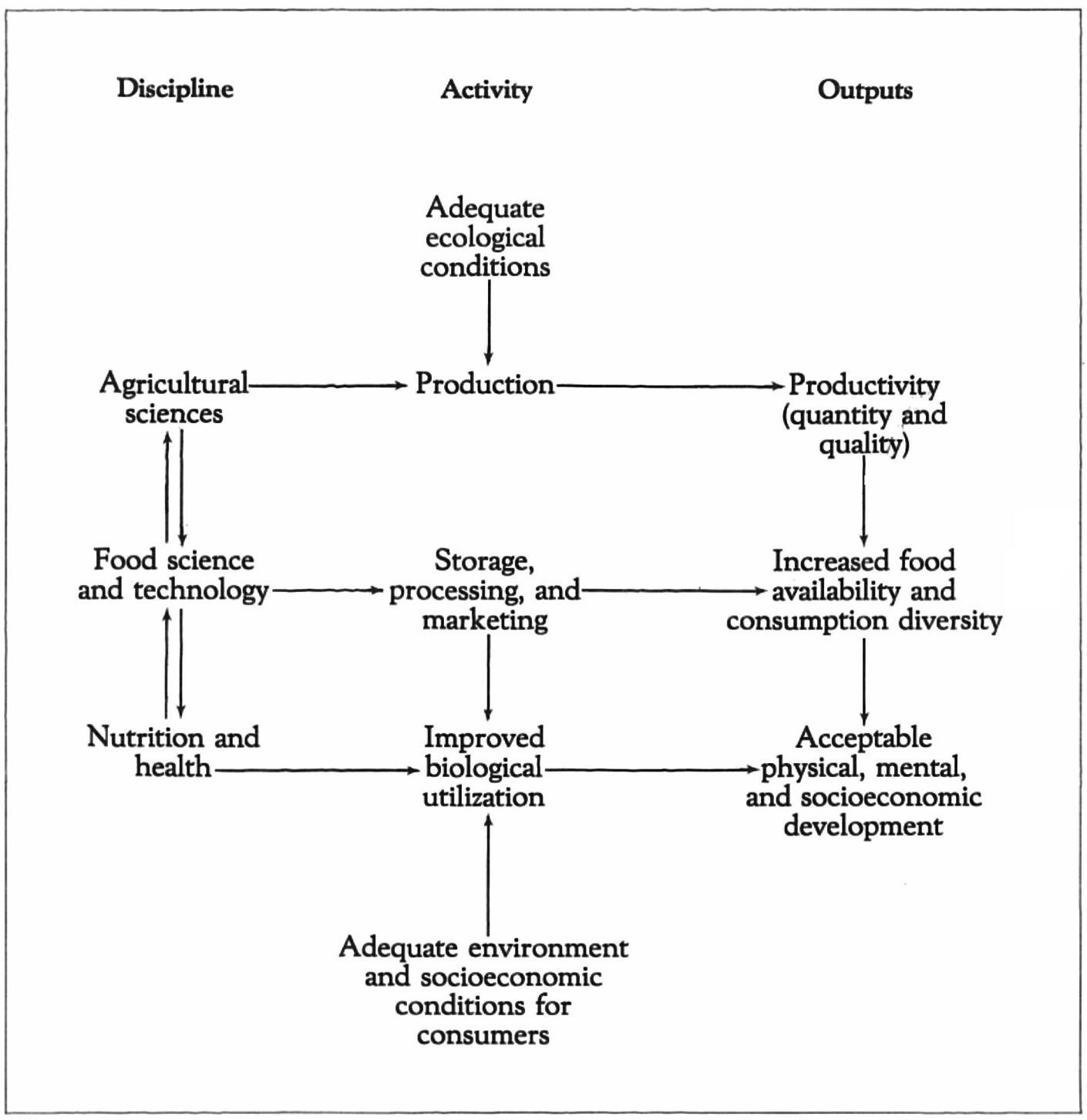

Fig. 9—**Multidisciplinary Approach** for delivering food and nutrition to consumers in the developing countries

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