world food situation have fluctuated widely and frequently over the last decade, but those in the network community have never had much doubt of the importance of their work. TAC chairman Crawford referred recently to the "Malthusian situation in which the world finds itself" with the comment that "At best, TAC believes research will buy time while population is brought under control." Many reject the extreme pessimism of the Malthusian view, yet when they do so it is almost always with the expectation that the few hundred people who staff the international centers will deliver what is expected of them.

References and Notes

1. For calendar year 1974 the donors and their contributions (in $000) were: United States (7000), Canada (4685), World Bank (3200), Rockefeller Foundation (3100), Ford Foundation (3000), Germany (2845), Britain (2015), Interamerican Development Bank, Washington, D.C. (2000), Sweden (1625), United Nations Development Programme (1450), International Development Research Center, Ottawa (930), Netherlands (605), Norway (430), Belgium (390), Denmark (370), Switzerland (290), Kellogg Foundation (280), Japan (270), France (125), and Australia (100). New donors in 1975 will include Nigeria and the United Nations Environment Programme.
2. D. G. Dalrymple, "Impact of the international institutes on crop production," paper given at the Airlie House symposium, January 1975, on international agricultural research, organized by the Agricultural Development Council, 630 Fifth Avenue, New York 10020. The ADC will have a conference summary prepared within a few months, and may later issue the proceedings as a book.
3. U. J. Grant, director of CIAT, presentation at International Centers' Week 1974, Washington, D.C. The directors' presentations are the main source of the notes on the various individual centers.
4. R. E. Evenson, "Comparative evidence on returns to investment in national and international research institutions," paper given at the Airlie House symposium.
5. H. Hanson, "Articulation of the international and national systems; the CIMMYT outreach program," paper given at the Airlie House symposium.
6. N. Brady, "Articulation of the international and national systems: the IRRI outreach program," paper given at the Airlie House symposium.
7. Figures are for the centers' "core" budget, or request from CGIAR, and do not include bilateral funds, which constitute some 15 percent of the average center's budget. Totals for the first six centers, taken from Dalrymple (2), include other sources of funds, such as earned income, but exclude special project funds.

Food Science in Developing Countries

Norman L. Brown and E. R. Pariser

One of the earliest organized efforts to identify and quantify the food and nutrition problems of developing countries was the series of World Food Surveys that were conducted by the Food and Agriculture Organization (FAO) of the United Nations starting in 1946. A little later the United States began to conduct a series of even more comprehensive food surveys in developing countries under the aegis of the Interdepartmental Committee on Nutrition for National Defense (ICNND) (*1*).

In the following remarks, we will attempt to describe some aspects of the response by aid-donor countries and the United Nations to nutritional problems in the less developed countries as they are revealed in these and similar nutrition surveys and investigations; we will further suggest some possible answers to the questions that this response has raised, and we will finally urge that the different distinct and complex food systems that exist in both developing and industrialized communities should be investigated by in-depth social anthropological studies to enhance the chances for successful nutrition intervention.

Response of Aid Donors to Food Needs

The usefulness of these global and national food surveys should not be underestimated, despite the inherent risks in making generalizations from such vast and complex undertakings that deal with large and disparate populations, each with a variety of food habits. They provided, by and large, an adequate clinical picture of the spectrum of foods consumed by the people studied. The ICNND studies in particular do not seem to have suffered from cultural bias; the overwhelming majority of the team members were host-country nationals, and all foods and beverages—including snack foods—were included in their surveys. It is safe to say that the FAO surveys provided a much needed baseline for nutrition policies and nutrition planning programs of both the United Nations and individual countries, and the ICNND surveys provided valuable detailed statistics and data on specific nutrients, foods, food habits, nutritional status, and some indication of the steps needed to attack specific regional malnutrition problems.

Once the problems were identified, however, the response of the aid-donor countries and the U.N. agencies was generally culturally biased. The conventional approach to the food problems of developing countries was, and still largely is, seen through Western eyes, and as a consequence Western technology has had a serious influence upon these countries in at least three ways: one is in the kinds of foods distributed in emergency situations and for long-term food aid; the second is the way in which educational institutions determine the outlook of the food scientist or technologist who works on problems typical of developing countries; and finally there is the effect that the export of the Western model of agriculture and other food production techniques has had on food production.

Export of food products. Aside from food grains, the United States and other industrialized countries distribute products of Western food technology such as dried skim milk (DSM), corn-soy-milk (CSM) mixtures, wheat-soy blends (WSB), and Incaparina. These products are wholesome and nutritious, and if consumed as intended will provide the valuable high-quality protein required by the target populations for adequate growth, development, and maintenance (*2*). Nevertheless, they are not part of the traditional diets, and in the case of DSM, CSM, and

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WSB, which are distributed free, there are numerous tales of misuse and nonuse that can be documented. The donor agencies tend to evaluate the effectiveness of such products in their reports by assuming that the children for whom they are intended actually receive and consume the intended daily ration. However, in many cases, even when the products are provided to children in controlled school feeding programs, actual measurements indicate that about 50 percent of the food is wasted (*3*).

Incaparina is an example of a nutritious food product created for production and use in a low-income market (*4*). The result of a prodigious development effort by INCAP (Instituto de Nutrición de Centro América y Panamá) to use locally available materials for the manufacture of a nutritious food, it has been on the market in Central America for 15 years. Nevertheless, it cannot by any means be considered to be a success in any conventional sense of the word; it does not reach a significant portion of the population for which it was designed, its manufacture is not profitable, and its beneficial impact on the national nutritional status is not noticeable.

Export of food technology. The second way in which Western influence is felt is in the export of technology in the education and training of food scientists and technologists. The products of American curricula are, on the whole, oriented toward problems of food processing, packaging, and distribution methods developed and used in the industrialized countries—with all that this implies in terms of access to raw materials, manufacturing technology, and chemical processing industries, and the vast infrastructure necessary to support all these activities. In a recent discussion of this problem, George F. Stewart (*5*) stated: "Few if any of the food science and technology curricula in industrialized nations are training students for the real jobs that exist in developing countries." In terms of those graduates from the industrialized nations—or those from less developed countries—who remain in the United States after graduation, there is simply the tendency to perpetuate Western approaches to Western food problems. To the extent that this represents a problem, it is of our own making. But in terms of the graduates who move on to international agencies or go—or return—to the less developed countries, we are creating for those countries a problem not of their making; we are supplying them with scientists and technologists to work directly on serious problems, and with professors who set up departments of food science and technology, yet all are grounded in curricula set up originally to meet our own needs.

In a recent publication of the National Academy of Sciences (NAS) (*6*), a leading food scientist from a developing country put the problem this way: ". . . a great portion of what food is produced [in developing countries] goes to waste on the farm, in the markets, and in the home. Proper food storage, processing, and packaging could make much more food available and encourage farmers to produce more. Yet, few workers in developing countries have been trained in these aspects of food science. Education and training in food science, as in other fields of science and engineering, suffer from the developed-country orientation of curricula designed and followed in institutions of higher education in both developed and developing countries. Most food scientists are trained for jobs that are unsuited to the developing country's needs and for which no funds are available. Scientists, nutritionists, and allied workers could contribute much more to their country's development now and in the future if their training were reoriented toward the problems that abound in their villages and towns."

Export of agricultural technology. The third way in which Western technology has affected the food situation in developing countries is in the export of Western agricultural technology. To say that the adoption of "modern" agricultural techniques by the food-deficit countries has been a mixed blessing is no longer as heretical as it was a few years ago. The Green Revolution, with its switch to crops amenable to mechanized farming and requiring irrigation and intense fertilization, has been viewed with considerable skepticism for some time because of its substitution of capital for labor and the consequent effect of increasing the economic gap between the wealthy farmer and the laborer in some situations (*7*). But other unforeseen—or ignored—aspects of monocropping are beginning to raise questions in the minds of some. Aside from the genetic vulnerability of such crops to attacks by insects and disease microorganisms (*8*), the effect on food quality has perhaps not been all that beneficial. For example (*9*): "Certain food plants are maladapted to monoculture whereas in traditional intercropping systems they become not only more productive, but they also encourage the growth of other food plants. Thus, the cereal stalk of sorghum or millet may provide a convenient support for climbing legumes and these return nitrogen to the soil. The clump of growing vegetation may provide sufficient shade to allow green leafy vegetables or fleshy fruits and vegetables to survive. Organizing these crops into an orderly rotated farming system would inevitably result in the loss of shade and possibly the vegetable crop. Such a situation arose during the initial experiments in applied nutrition at Hyderabad in India, in the early 1960's. Attempts to show local inhabitants the advantage of producing lettuce and cabbage by methods used in temperate climates were disastrous, since survival of the vegetables in the hot and arid Deccan [plain] could only be achieved by applying much water, a precious commodity at the best of times."

The Western "mass cultivation" approach to agriculture has another consequence which is perhaps more serious. One normally associates dietary variety with the affluent industrialized nations and restricted dietary choices with developing countries. However, in actuality the number and variety of indigenous foods traditionally eaten in less developed countries is quite large, while the apparent large variety of foods available in affluent societies "represent(s) permutations and combinations of a very limited number of food resources" (*9*). This tendency to decrease the number of different food resources consumed may have serious long-term effects with respect to toxicants naturally occurring in foods. Even in this age of food additives, more than 99 percent of our daily diet consists of the naturally occurring chemical components of the foods we consume, and among these is a variety of naturally occurring substances which may be, or have been shown to be, toxic under certain circumstances (*10*). This is not to say they necessarily constitute a hazard, because the potential toxicity may not give rise to any injury; rather, the toxicity may depend on the circumstances, such as conditions of food preparation, quantity ingested, or antagonistic interactions with other food components. It is the two last-named conditions that become important in evaluating the wisdom of limiting the variety of foods in a diet, and illustrate what has been called the "concept of the *safety in numbers* as applied to the chemical components of the diet" (*11*). Thus, not only are the chances lowered that a particular naturally occurring toxicant will be consumed to a hazardous degree, but the chances are raised that the multitudinous antagonistic reactions possible among such substances will act as a protective device if the diet contains the widest possible variety of foods.

The Study of Food Systems

In a lecture entitled "Food as an art form," given to the Royal Anthropological Institute of London in May 1974, Professor Mary Douglas raised a number of considerations that are, or should be, of crucial importance to nutrition planners (*12*). In the absence of adequate answers to many of the questions that Professor Douglas asked, it appears to us that food and nutrition planning, and the development and large-scale acceptance and use of new foods and food supplements, will remain largely a matter of chance, especially in developing countries with their frequently conservative and unique food consumption patterns.

Professor Douglas points out that since food is consumed partly because of the biological function it serves, and partly because it also has a very clear esthetic function, it is similar in many ways to clothing, architecture, and utensil design. To understand properly the way in which food is viewed, manufactured, and utilized in different societies, it must be considered just like the other necessities of life just mentioned. Food is a system that is made up of a series of temporal, spatial, and sensory events combined according to certain rules. These rules are practically always unwritten but they are nonetheless precise, rigorous, and well-known within a particular society. Knowledge of the rules that govern a particular food system is essential if it is desired to make changes in the system. It is, for instance, vital to know how eclectic a particular system is in regard to the range of materials and ingredients it tolerates. Are there some parts, Professor Douglas asks, that are very stable and others that are more experimental? It is clear that a precise answer to these questions would have an important bearing on the nutritionist's decision as to where in the system efforts to introduce a dietary change should be directed.

A similar question addresses the degree of freedom characteristic of one kind of food in one or another type of setting. How much is the preparation of the food made visible, how much is kept offstage? How important are the sensory qualities of foods belonging to the system under investigation? How important is it that a particular food be hard or soft, gritty or smoothly textured? Where and when and how do the sensory qualities of the particular type of food outweigh its real or imagined nutritional qualities? What odors, tastes, and colors are permitted, and in what types of food for what occasion? Another point of investigation of considerable importance to the nutritionist engaged in food relief to a community is the effect of pressures of the social, economic, and religious systems upon the food system. Do these pressures enhance or diminish flexibility, and are there differences in the effects that a stagnating or a rapidly changing social system has upon a food consumption pattern?

These and many more such questions relating to the rules according to which foods are prepared, sold, and consumed in a society are very rarely asked, and they are certainly difficult to answer. We suggest here, however, that correct responses promise to increase significantly the chance for a successful nutrition intervention.

Possible Solutions

There are several ways in which Western technology can be made more useful in helping the food-deficit nations solve their food problems. One thing which seems obvious is that some serious rethinking must be done about the objective of our food science and technology education, primarily in terms of its usefulness when faced with conditions and food problems completely foreign to Western experience. We have rendered a disservice to food scientists from—and in—developing countries when, as a result of their education, they tend to concern themselves with the types of packaging, preservation, flavoring, coloring, texture, "mouth-feel" problems associated with the processed convenience foods of the United States or other industrialized communities. Some people in U.S., Canadian, and European universities have begun to be concerned about this, and there are courses of study now which are beginning to take these problems into account. Some examples of the schools involved in this way are: Iowa State University, Purdue University, University of Rhode Island, University of Florida, University of Manitoba, Northern Alberta Institute of Technology, and the Agricultural University at Wageningen (*13*).

Some steps are also being taken in developing countries to reorient the education of food scientists and technologists. The University of Ghana (*14*) and the University of Ife (*15*) are two examples, but one of the major efforts is being made at the International Food Technology Training Center in Mysore, India. This institute was established in 1964 with FAO assistance, at the Central Food Technology Research Institute (CFTRI) (which has long been working in food research and which has achieved some notable successes in applying modern food science and technology to local conditions in South and Southeast Asia), and offers both a master's degree in science and a program for continuing professional education (*5*).

Another approach to directing the attention of students, professors, and government and industrial laboratory scientists—in both the industrialized and nonindustrialized nations—to specific problems of developing countries has been taken by the NAS. Through its Advisory Committee on Technology Innovation the NAS has published *Food Science in Developing Countries: A Selection of Unsolved Problems* (see *6*), a compendium of problems in food science and nutrition selected primarily by scientists and other workers in the less developed countries as topics worth immediate examination. Thus, the publication represents a view of priorities which is "theirs" and not necessarily "ours," and is intended to stimulate the interest of research workers and technologists in solving these and similar problems. The problems are presented in a uniform format (*16*) (problem description, background information, possible approaches to a solution, special requirements, bibliography), and each problem concludes with the name of one or more "key contacts" who have agreed to act "as personal contacts to whom the interested reader may turn for advice and information while getting started on the research suggested . . . or during the course of the investigation" (*6*).

Some examples from this publication

will help illustrate what we have been talking about in this discussion. The first concerns the use of oilseed cake from traditional oil-extraction processes. In Ghana, for example, the traditional method for vegetable oil production is water extraction, but this removes only about 30 percent of the oil present in the seed. Because of its high oil content the residue is unsuitable for use as animal feed and is difficult to process further by local methods, for use as human food. The tragedy in this situation is that oilseed cakes are excellent sources of protein and calories for supplementing deficient diets. The article points out: "Because small, traditional processors are widely scattered, any attempt to gather presscake for further processing takes so long that both oil and protein residues deteriorate, which discourages further processing. Since the small-scale, traditional method of vegetable-oil production cannot yet be discontinued, any method that improves the efficiency of the water-extraction process will strengthen the vegetable-oil industry of countries like Ghana. If the traditional process could be modified to stabilize the residues, protein-short countries could use valuable oilseed protein in foods" (*6*, pp. 3–4). Some possible approaches are suggested, a bibliography is given, and two key contacts are listed, one in Ghana (the contributor) and one in the United States.

The second example is a problem entitled "Milling quinua seeds" (*6*, pp. 34–36). The contributor of this problem begins by discussing the need for protein, especially with young children, and the unavailability of milk, for a variety of reasons, to large populations. He then reminds us of the existence of quinua (*Chenopodium quinoa*), a little-known plant which has a long history of use in human foods in Latin America, particularly Peru. This plant produces a grain with a high protein content, but even in its country of origin (Peru) its use is hampered because traditional methods of processing do not uniformly remove the undesirable flavor characteristics of some of its constituents (saponins). The discussion goes on to point out that those constituents seem to be present in the outer layer of the seed but, because of the shape of the seed, conventional milling techniques do not always remove them. The possible solutions suggested involve three approaches: (i) develop new milling techniques or equipment; (ii) experiment with altering the flavor components of the seed by varying cultivation techniques combined with genetic selection to increase grain size, alter the seed shape, and/or reduce the saponin content and (iii) concentrate on the removal of saponin by improvement of the traditional extraction techniques. Again, a bibliography is given; the key contact listed, in this case the contributor, is in Peru (*17*).

These two problems illustrate two of the points outlined at the beginning of the previous section. The first is the value, or rather the necessity, of using the best of Western technology to improve upon, rather than displace, traditional food processing techniques. Where this is possible, it is certainly more desirable, in terms of rapid acceptability, use of local skills, materials and equipment, and low cost, than beginning with the assumption that the traditional processes are primitive, useless, outmoded, and should be replaced—with all the implications of this approach in terms of new, "modern" equipment and the foreign exchange needed to purchase it. The second point illustrated is the wisdom of examining the culture to see what traditional crops exist whose nutritional impact on the diet might be enhanced with the input of some modern technology—rather than deliberately displacing such crops with others more amenable to mechanical mass cultivation (*18*).

Finally, a third example from the NAS publication serves to illustrate a third point, namely, that Western technology can be usefully applied to problems in developing countries by selecting the techniques best suited to improving a traditional food. In "Indigenous sources of enzymes for more rapid fermentation of fish (*6*, p. 23), the problem of the time required for traditional processing is discussed. In these processes, where the endogenous enzymes of fish produce the traditional fermented fish pastes and fish sauces ubiquitous throughout Asia, sometimes 8 to 10 months are required for the fermentation to be completed. The contributors of this problem suggest that by applying modern enzyme technology, it might be possible to use other known proteolytic enzymes of plant or fungal origin to accelerate the traditional process without disturbing traditional flavors and textures. Four key contacts are listed, two of them being in Asia and two in the United States.

Summary and Conclusions

It is particularly important for us not to lose sight of the fact that people have been around for a long time and that they achieved remarkable technical skills long before Western science was developed. An anonymous writer from the Food and Agriculture Organization has observed: "It is a commonplace that the fundamental discoveries which made civilization possible—fire-making, tool-making, agriculture, building, calculating, writing, money—were all apparently made outside the area which has given us the marvels of modern science" (*19*). The writer might well have added that it is also commonly overlooked that food technology was not suddenly developed in the 20th century but has been very much a part of the lives of people everywhere ever since they began doing more to their food than gathering it and eating it raw. Lamb's "Essay on Roast Pig" may not be an accurate account of the first conjunction of fire and food, but cooking is a rather ancient practice. Fermentation is another complicated processing technology which is a traditional part of most cultures, particularly those in warm climates—beer, yogurt, cheese, the fish pastes and sauces of Asia, the palm wine of Africa, and soy sauce, are but some examples. Native Americans, besides accomplishing marvels in plant genetics and crop development, also developed water extraction methods for treating acorns to render the flour palatable and edible, and the alkali method of processing maize. Furthermore, they developed a cure for scurvy—by making a water extraction of pine needles which are rich in ascorbic acid—long before it was first reported by Jacques Cartier in the 16th century. Similarly, calcium-deficient diets of pregnant and nursing women were traditionally successfully supplemented by calcium-rich powdered deer antlers in northern China. Among the Chinese and Greeks, goiter was cured by eating certain kinds of seaweed centuries before the disease was traced to a lack of iodine, and Kenyans learned to suck salt-rich earth to avoid salt depletion symptoms after arduous exertion in tropical heat long before "modern science" learned why (*20*).

The enumeration of examples could go on, but this was not meant to be an essay in folklore. The point is that all so-called primitive societies developed technologies, techniques, and a store of practical knowledge of a wide range of sophistication, by what must be admitted to be the scientific method, and neither their accomplishments and skills nor those of societies "en voie de développement" should be ignored or discounted.

We are confident that modern food science and technology has much to contribute to helping the food-deficit nations eat adequately. First, we must find a way of using the best of Western technology without losing sight of the reality of the situation in the third world and without failing to take into account, better than we have done so far, the secondary and tertiary implications of the changes suggested. Second, we must encourage the examination of local problems in terms of the use and improvement of local technologies which are often quite sophisticated and the result of centuries of development. And third, we must inject a greater component of cultural awareness in the education of students to make them more creative in their application of scientific knowledge to local problems and more adaptable to the conditions that exist in developing countries. We should not lose sight of the fact that because of the precarious nature of their food supply, very often developing countries have much more rigid rules governing the production, preparation, and consumption of food than usually is the case in food-surplus societies, and disturbing these rules is a very serious matter. The time is past when "West is best" can be taken for granted; "adapt and adopt" is surely less offensively arrogant and much more to the point.

References and Notes

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14. R. Oracca-Teteh, personal communication.
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16. The format is similar to that used in a previous publication (now out of print) which proved popular with students in the United States: *101 Problems in Food Science and Technology*, C. O. Chichester *et al.*, Eds. (Department of Health, Education, and Welfare, Washington, D.C., 1969).
17. This presentation is not meant to imply that no other efforts exist to direct the attention of food scientists and technologists to specific problems of developing countries. For instance, the CFTRI previously mentioned has long been engaged in such an effort in Asia; the Caribbean Food and Nutrition Institute (Trinidad and Jamaica) does this in the Caribbean; and INCAP is well-known for its work in Central and South America.
18. A related problem which fortunately has no counterpart in modern times was the displacement of *Amaranthus edulis*, a nutritious grain, in favor of maize by the Aztecs, for religious and politicoeconomic reasons of the priestly ruling class.
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Crop Protection to Increase Food Supplies

W. B. Ennis, Jr., W. M. Dowler, W. Klassen

The need for enough food to insure against hunger or the fear of famine was probably one of the strongest motivating forces in history, and the threat of starvation remains a primary concern in many nations. In countries where adequate food is available, consumers are greatly troubled about costs.

Today, pests cause an estimated 30 percent annual loss in the potential worldwide production of crops, livestock, and forests. No part of our food, feed, or fiber supply is immune from pest attack, whether it involves marine life, wild or domestic animals, field crops, horticultural crops, or wild plants. Obviously if losses could be prevented or reduced food supplies would be increased. Although the problems are complex, the best strategy for achieving short-term gains is to make better use of existing technologies in production systems throughout the world.

Nature and Extent of Losses Caused by Pests

Pests of many kinds attack plants during all stages of their growth and attack food or food products after harvest—in storage, during transportation to market, in warehouses, in elevators, in ships, in the supermarket, and in the home after purchase. More than 160 bacteria, 250 viruses, and 8000 fungi are known to cause plant diseases in one situation or another (*1*). Approximately 10,000 species of insects in the United States are destructive enough to be called enemies. About four-fifths of them are injurious to crops (*2*). Likewise, some 2000 species of weeds in the United States and Canada cause economic losses in some crops or situations (*3*). In addition, a wide range of nematode species, birds, rodents, and other organisms continually attack our crops and food supply.

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