Educational Programs in Food Science: A Continuing Struggle for Legitimacy, Respect, and Recognition

O. Fennema

The image of food science is muddled. Typical high school seniors and high school counselors are unable to conjure up an accurate mental image of what food science is all about (Anonymous, 1982; Hegener and Hunter, 1980). What relevance does this have to the history of educational programs in food science? Plenty. This is not meant to be critical, since our profession has matured greatly since its origin in the early 1900s, and a better course of maturation, at least one that would have been feasible, is hard to imagine. This article will explain what has led to this muddled image and present ways to help rectify this situation.

The Muddled Image of Food Science

The roots of food science lie in two disciplines—food chemistry, mainly analytical chemistry as it developed in the late 1800s and early 1900s, and microbiology, beginning with the work of Pasteur (Bushill, 1968). Food engineering was a latecomer to the fold. The development of food science departments and their course offerings followed closely the transitions in the food industry. In the early 1900s, food companies were small, technologically unrefined, and poorly regulated. Artisans, tradesmen, and the like were the type of personnel most needed. Gradually, food companies became larger, technologically more sophisticated, and better regulated, creating a need for personnel with greater skills.

In 1913, two universities, Massachusetts Institute of Technology and Oregon State University, responded to existing technological needs of the food industry by offering the first courses in food technology (Prescott, 1950; Proctor, 1950; Schultz, 1964). During 1920–50, a few university curricula in food technology (about five, depending on the criteria used) were developed (Schultz, 1964). Thus, creation of the Institute of Food Technologists in 1939 occurred when university education in food technology was in its infancy.

The rapid growth phase for establishment of university programs in food science occurred during the 1950s and '60s (Livingston, 1972). These departments were generally formed by restructuring a single-commodity department, such as dairy processing, animal science, or horticulture, or merging several single-commodity departments (Lineback, 1986). During the latter stages of this period, many departments of foods and nutrition were absorbed into food science departments.

Accompanying the rapid establishment of these new departments was a proliferation of departmental names and dramatic changes in curricula. Names such as Dairy and Food Science, Food Science and Industries, Horticulture Processing, Food Technology and Nutrition, Food Science and Biochemistry, Nutrition and Food Science, and Food Science and Technology emerged, with Food Science and Food Science and Nutrition eventually becoming most common.

Most food science curricula in the 1950s were strongly oriented to commodities, and this probably corresponded fairly well to industry needs at that time. Since then, courses in specific commodities have been deemphasized, with the new emphasis being given to pertinent background sciences, and to scientific principles that apply to all foods, or at least to large groups of foods. Again, this change reflects the transition of the food industry in the direction of larger, technically more-sophisticated companies.

The development of food science undergraduate curricula in the United States was influenced greatly by the establishment in 1958 of an IFT "model curriculum" (Schaffner, 1958), and by the formalization in 1966 and 1977 of guidelines ("minimum standards") pertaining to undergraduate curricula (Anonymous, 1962; 1966; 1977; Schaffner, 1958).

Considering the dramatic changes that have occurred in the names of food science departments and the profound alterations in curricula, small wonder that food science has a muddled image.

Before leaving the historical component of this article, I would like to draw attention to a fascinating document—the first report of the IFT Committee on Education and...
Curricula, which was issued in 1944 (Stewart, 1947). The following propositions were considered to be requisite for a satisfactory curriculum in food technology:

A. That the students first acquire as a foundation certain basic courses applicable to all phases of food technology; such as courses in chemistry, physics, mathematics, microbiology and biological chemistry.

B. That it is impossible for any person to become proficient in all phases of food technology and therefore it would be better to train students in the basic sciences with perhaps a limited knowledge of their application to food technology, rather than to turn out students with a superficial knowledge of a large number of food industries and operations but lacking in basic training.

C. That the students' specialized training in the application of these basic science principles to the field of food technology be reserved for periods toward the end of their college training.

D. That the student acquire some knowledge of the principles of engineering, either in the field of mechanical engineering or in the field of chemical engineering.

E. That the student acquire training in subject matter auxiliary to the scientific training but very necessary to his proper functioning in industry; such as law, business, accounting, statistics, personnel relationships, English, report writing, recordkeeping, geographical agriculture.

F. That it is probably not desirable for all students to receive the same training. Some might specialize in the sanitary aspects of food technology, others in the biochemical, physical, organic, or the engineering, but all should have such a knowledge of the field as a whole as to enable them to understand the literature and language of the whole field.

G. That during summer vacations a student work in food processing plants or perhaps drop out during his college course to gain a year of practical experience in a processing plant.

H. That probably five years of college work will be required.

I find it nothing short of incredible that these propositions, composed 45 years ago, describe so well the current beliefs of leading educators in food science.

Our profession has matured greatly since its origin in the early 1900s.
Educational Programs (continued)

The Current Situation and Trends

It is appropriate to comment briefly about colleges of agriculture, since most food science departments are administratively situated in colleges or schools of this kind and it is obvious that they have a bearing on food science departments.

In general, undergraduate enrollments in agriculture are declining; graduate-level enrollments are fairly constant (Bruene et al., 1987); the student body is increasingly nonrural in background; and the quality of entering students, on the basis of Scholastic Aptitude Test (SAT) and Graduate Record Examination (GRE) scores, is below that of the average student entering the physical and biological sciences, medicine, and engineering (Anonymous, 1985; Smith, 1986).

To persons not well acquainted with colleges of agriculture, the image is usually one of cows, farms, and shallow science—none too helpful in recruiting top-quality, science-oriented high school students into food science programs that also are afflicted with a muddled image.

Approximately 69 U.S. universities offer programs that can be broadly categorized as food science, and 42 of these offer one or more curricula that meet the IFT minimum standards (Anonymous, 1977; 1986). The number of degrees awarded in food science and various sub-areas during 1982–85 are shown in Table 1. It is apparent that the number of B.S. and M.S. degrees awarded in recent years do not follow a distinct trend, but annually average about 1,300 and 350, respectively. The number of Ph.D. degrees awarded annually during 1982–85 has tended to increase and in 1985 was 161.

A few other relevant points that are poorly documented but generally believed to represent national trends are as follows:

- The proportion of females enrolled in food science has increased during the past 10 years to a point where females exceed males in many undergraduate programs; the ratio is approaching one to one in graduate programs, and more females than males win IFT-administered scholarships and fellowships.
- Freshmen enrolled in food science continue to represent a small part of the total undergraduate enrollment in most departments of food science.
- Something on the order of 50% of the students entering graduate programs in food science do not hold undergraduate degrees in food science.
- A sizable proportion of the students enrolled in graduate programs in food science are not U.S. citizens, and most of the foreign students come from lesser-developed countries.

To assess program quality in a food science department, one must consider as relevant components the students, faculty, curricula, and resources/facilities.

<table>
<thead>
<tr>
<th>Department or subspecialty</th>
<th>Year</th>
<th>B.S.</th>
<th>M.S.</th>
<th>Ph.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Science/ Human Nutrition</td>
<td>1982</td>
<td>1,034</td>
<td>388</td>
<td>124</td>
</tr>
<tr>
<td>1983</td>
<td>1,232</td>
<td>326</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>1,251</td>
<td>396</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>1,329</td>
<td>322</td>
<td>161</td>
<td></td>
</tr>
<tr>
<td>Subspecialty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Sciences, General</td>
<td>1985</td>
<td>499</td>
<td>233</td>
<td>101</td>
</tr>
<tr>
<td>Dairy Processing</td>
<td>1985</td>
<td>25</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Food Distribution</td>
<td>1985</td>
<td>186</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food Engineering</td>
<td>1985</td>
<td>6</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Food Packaging</td>
<td>1985</td>
<td>189</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Food Technology</td>
<td>1985</td>
<td>98</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>Nutritional Sciences</td>
<td>1985</td>
<td>326</td>
<td>73</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 2—Suggested Criteria for assessing new options in food science

- Specialty courses in the proposed option must have an intellectual content consistent with accepted university standards; i.e., courses dealing with "tricks of the trade" should be avoided, and courses dealing with long-enduring principles of substantial importance should be stressed.
- Primary aspects of the option must be compatible with a strong, science-based program in food science; i.e., the option must not subvert science prerequisites and core courses that are normally required in the food science program. An obvious result is that the option may require five years to complete.
- The anticipated pool of students entering the option must be sufficient to permit specialty courses in the option to be offered at least once annually with enrollments sufficient to satisfy the university's minimum requirements.
- Faculty should be sufficient in number and expertise to teach, in an academically acceptable manner, all specialty courses required in the option.
For information circle 201

LUXTRON
1060 Terra Bella Ave., Mountain View, CA 94043 Tel: (415) 962-8110 Fax: (415) 961-5978

DO YOU KNOW
THE PRODUCT AND PACKAGE TEMPERATURE
INSIDE YOUR MICROWAVE OVEN?

Take the guesswork out of microwave food product development. Measuring temperatures in the oven is the only way to optimize microwave product performance.

Whether you're developing prepared foods or "active" packaging, Luxtron has the solution.

Luxtron's unique fiber optic thermometer will save you time and money. This system makes reliable surface or immersion measurements at multiple points during the microwave cooking process.

The flexible fiber optic probes are unaffected by microwave energy making them completely microwave oven compatible. Measurements are easy, repeatable and require no calibration.

For over 10 years, Luxtron has set the industry standards for reliable, real-time, in-the-oven temperature measurements.

Take the guesswork out of your microwave food product development, call or write Luxtron and let the leader in fiber optic thermometry help make your product a market leader.

1060 Terra Bella Ave., Mountain View, CA 94043 Tel: (415) 962-8110 Fax: (415) 961-5978

For information circle 201

Educational Programs (continued)

scores, and ratios of applicants to acceptees in the department.

Currently available data on SAT and GRE scores are not useful for evaluating students in food science because these tests do not include "Food Science" as one of their statistical categories. For SATs, the most detailed category containing food science is "Agriculture," and for GREs the most detailed category is "Applied Biology" (Anonymous, 1985; Smith, 1986). Judgments on the quality of students in food science must, therefore, be based on other considerations, and the only meaningful remarks I can make concern graduate students.

It is my opinion that typical graduate students in food science are usually not the worst, nor the best, among the spectrum of graduate students in science-based departments at typical universities. There are two rather compelling observations that support this statement:

First, it would be extremely difficult for a department to claim that it is rigorously screening the quality of entering graduate students, unless applicants are abundant enough that some domestic students with GPAs of 3.2 (4.0 basis) or greater and GRE scores of 1,200 (verbal + quantitative) or greater are routinely rejected because more qualified persons are available. If a U.S. food science department exists that is able to operate in this fashion, its identity is unknown to me. Yet, some basic science departments are able to function in this manner. It is also apparent that some departments of food science are able to attract larger numbers of high-quality graduate students than others, leading to the conclusion that the quality of graduate students in food science varies significantly from one university to another.

Second, if one assumes that most departments of food science are accepting students who are less well qualified than those in other highly regarded, science-based departments (which I believe to be true when considering all U.S. departments of food science), then to assure that students receiving advanced degrees conform to acceptably high standards, some of the entering students should regularly fail to complete their degrees because of shortcomings in expected capabilities. It is my observation that this does not generally occur, for two reasons: (1) It is difficult to assess with reasonable accuracy and unanimity of opinion the kind and nature of deficiencies in capabilities that are sufficient to cause a degree candidate to fail; and (2) professors are reluctant to fail students who are well into their research because of the need to produce timely research results for granting agencies. Thus, if students are admitted to graduate programs in food science, they are likely to graduate, provided that they (1) maintain an acceptable GPA in course work, (2) develop moderately adequate laboratory skills, and (3) display a reasonable level of determination. When these conditions are satisfied, and they usually are, then admission is tantamount to graduation. This situation need not be undesirable, provided that the quality of students being admitted is sufficiently high (e.g., as in medical schools), but this is often not true in food science programs.

The number of students also has an impact on program quality. Many departments of food science have too few students, which often results in an
Typical graduate students in food science are usually not the worst, nor the best, among the spectrum of graduate students in science-based departments at typical universities.

inability of the department to offer the range of courses generally deemed appropriate for a high-quality program.

- Faculty. Discussion of this important aspect will be short, since data are unavailable. The pertinent questions are, "Is faculty quality improving?" and "How does the quality of faculty in food science compare to that in other highly regarded scientific fields?"

Based on personal observations of various departments of food science and of universities in general, and on discussions with other professors in food science, it would seem safe to conclude that faculty quality in food science is following a steady trend of improvement. This is clearly true with respect to competency in pertinent analytical skills, but less certain with regard to innate intellectual qualities. I am persuaded that average faculty quality in food science is not quite equal to that of faculty in departments involved with more-basic sciences. This conclusion, although unsubstantiated, is not illogical, based on the relative newness and still-developing academic stature of the field of food science, the average quality of Ph.D. students graduating from departments of food science (these are the primary source of faculty members in food science), and the lack of intense competition for open academic positions in food science.

The number of faculty also has a bearing on program quality. Many departments are still plagued by having too few faculty members. This has several undesirable consequences: (1) faculty members are required to teach a broad array of courses, some involving subject matter in which they may not be highly proficient; (2) high-quality, graduate-level courses in food science will be inadequate in number; (3) teaching and public-service obliga-
Educational Programs (continued)

...time-consuming to impair a faculty member's ability to establish a sound research program—an essential part of high-quality, graduate-level education; and (4) few opportunities will exist to hire discipline-oriented faculty members who can contribute greatly to in-depth teaching and research programs.

- Curricula. Quality of the curriculum at the undergraduate level has clearly improved during the past 20 years, and the IFT minimum standards have helped greatly in this regard. However, curriculum quality at both the undergraduate and graduate levels is, not surprisingly, highly dependent on the specific food science department and also on the quality of departments that provide supporting courses required in food science programs.

A definite bright spot with respect to curriculum is that textbooks for food science have risen from a point of critical inadequacy in the 1950s to acceptability for most subject areas in 1989.

At the graduate level, nothing comparable to the IFT undergraduate guidelines have been developed. Thus, considerable variability in program design exists among the various departments of food science. This has some desirable aspects, but contributes to at least two problems. A graduate-level degree in food science from one university may represent qualifications quite different from those expected at another university. This does not help clarify the image of food science. Furthermore, under this system, a desirable national dialogue does not exist to the extent that it should, regarding goals and solutions to problems that are common to almost all graduate-level programs in food science.

- Facilities and Resources. Not to be forgotten in evaluating program quality is the adequacy of facilities, equipment, instrumentation, libraries, and operating funds. Unquestionably, facilities for food science have, in general, improved markedly during the past 20-30 years. However, many instances can still be found where facilities are substandard to the point at which program effectiveness is adversely influenced. Moreover, it is not difficult to find food science programs in major universities where serious problems exist with respect to the quality of facilities. This is likely to be slow, so future changes are likely to continue and should be prominently publicized in titles and information describing our profession.

- Refinement of the basic undergraduate program in food science is a subject of active discussion, and this is healthy. Some have suggested that options in areas such as quality assurance (Blanchfield, 1980; Lawrence, 1980; Nelson, 1978), nutrition (Francis, 1977), food engineering (Toledo, 1977), processing (Lukes, 1977), and business management (Miller, 1977) should be accommodated in the IFT minimum standards. Suggestions such as these are worthy of careful assessment, but implementation should be done with care, because in some instances establishment of the option can undermine the core science requirements that are generally recognized as essential in any food science degree program. Criteria which I consider useful in assessing the appropriateness of any new option are listed in Table 2.

Others believe that B.S. graduates in food science are deficient in communication skills (a vigorously registered and common observation by industry scientists; Bauman, 1979; Buchanan, 1972; Lauro, 1977; Sloan and Labura, 1979), skills in human relations (Albrecht, 1979), food law (Bauman, 1979; Hutt, 1985; Lauro, 1977), problem solving, knowledge of the ethical and legal aspects of food microbiology, and laboratory skills needed for graduate studies. Obviously, the minimum curriculum requirements cannot be expanded to accommodate all of these suggested needs. The only reasonable approach, it seems to me, is for the IFT Committee on Education to conduct surveys and workshops to ascertain, from a sizable and representative sample of food scientists, what are the strengths and weaknesses of our current minimum standards. Only then can sound recommendations for change be formulated.

- Yet another suggestion deserving serious attention is an internship program for science-oriented, college-bound high school students. This could involve summer placement of these students in food companies just before their freshman year in college, with the most outstanding students being accommodated in research facilities and the remainder in production facilities. This could be a powerful tool for recruiting capable high school students into food science programs—currently a serious national deficiency.

- A few individuals have also observed that current doctoral programs in food science do not provide the kind of education which is most appropriate for those students intending to pursue careers in lesser-developed countries (Bourne, 1980). The criticism is that, in addition to current Ph.D. requirements, these students need to be exposed to a broad array of practical, hands-on experiences. This is a valid observation that deserves careful consideration. But extreme care needs to be exerted to assure that current standards in food science doctoral programs, which have been painstakingly established over many years, are not subverted by new programs of this kind. My suggestion would be that interested individuals be allowed to engage in a one-year, post-Ph.D. residency in industry or government, where these needed practical skills can be gained.

- A need exists to monitor the...
quality of students entering food science programs. This can be done by collecting information on high school rank and SAT scores of students entering undergraduate programs in food science, and on GRE scores and GPAs of students entering graduate programs in food science. This information would allow student quality in food science to be compared to that in other science-based fields, trends in student quality to be determined, and the effectiveness of recruiting efforts to be assessed.

A Few Philosophical Points

I will close this article with proposed guidelines for assessing the strength of undergraduate and graduate programs in food science; but before doing so, I believe it is appropriate to raise a few points that provide a philosophical background. These views are, of course, my personal opinions, but they are shared by a good many of my respected colleagues:

1. Above all else, graduates in food science must be well grounded in pertinent background sciences such as physics, mathematics, biology, microbiology, and various subspecialties of chemistry (inorganic, organic, physical, and biochemistry).

2. The background sciences must be well integrated into the core food science courses, with emphasis given to long-enduring scientific principles and critical thinking rather than to commodity-specific approaches. Two quotations are appropriate in support of this position. The first is by R.M. Hutchins, former president of the University of Chicago (Hutchins, 1953):

   Universities are not well adapted to teaching the tricks of trades. And it is unwise for them to make the attempt. The great problem of the university is the problem of purpose. What is it for? If it undertakes to teach the tricks of some trades, why should it not be willing to assume the same responsibility with regard to any? But why should it try? Unless its professors are engaged in the practice of the occupation, they are unlikely to be adept at the latest tricks; and, if they are actively engaged in the occupation, they are unlikely to be good professors. This is not because of any defect in their character but because the demands of active professional life do not allow them time for study and reflection. The best division of responsibility between the university and the occupation would be to have the university deal with the intellectual content of the occupation, if there is any, and to have the occupation itself take charge of familiarizing its own neophytes with the technical operations they have to learn.

   The second quotation is from the 1962 IFT Conference on Undergraduate Education in Food Science and Technology (Anonymous, 1962):

   In discussing the required courses, some industry representatives expressed satisfaction in that progress had been considerable in improving the caliber and content of Food Science courses since the First Educational Conference. However, there was criticism of the amount of time devot-
Educational Programs (continued)

ed to descriptions of practices and processes, particularly in relation to individual commodities or groups of commodities. Industry representatives stated that a student could readily learn industry practices and details pertaining to individual commodities during industrial employment, and it was suggested that if a student is able to learn a subject within industry, then that subject should not be taught at a university. This would afford a university more time for instruction in the basic sciences and principles of food processing. It was further suggested that greater emphasis be placed on teaching students to think quantitatively and encourage them in the application of principles, rather than in accumulating descriptive information that is generally common knowledge to industry people.

I should hasten to add that adoption of this philosophy should in no way discourage the offering or commodity courses on an elective basis, provided that they are taught in a manner consistent with accepted university standards; or of conducting research on commodities, provided that this research is conducted in a manner compatible with sound graduate-level education.

3. The approach to core courses in food science should be (and increasingly is) predominantly quantitative rather than descriptive. The increasing influence of food engineers on the food science curriculum has been especially positive in this regard.

4. The concept of options in food science, especially at the undergraduate level, should be approached with great caution. It seems likely that proliferation of options at the undergraduate level cannot occur without sacri-

<table>
<thead>
<tr>
<th>Table 3—Proposed Guidelines for assessing the strength of existing or proposed academic programs in food science</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Curriculum</strong></td>
</tr>
<tr>
<td>• Does the department offer high-quality courses that are sufficient in kind and number to cover the subject matter deemed essential for the degree program? Are the course requirements in accord with standards developed by a relevant professional organization?</td>
</tr>
<tr>
<td>• Are essential courses from supporting departments of a kind and quality that equal or exceed standards applied to courses in the major?</td>
</tr>
<tr>
<td>• At the M.S. level, are several high-quality, advanced-level courses required that are not required at the B.S. level?</td>
</tr>
<tr>
<td>• At the doctoral level, are several high-quality, advanced-level courses required that are not required at the M.S. level?</td>
</tr>
<tr>
<td>• For graduate programs, has the department established minimum course requirements that must be fulfilled by all graduate students regardless of subspecialty?</td>
</tr>
<tr>
<td>• Especially with regard to subspecialties, is the intellectual content of the program in accordance with generally accepted university standards that prevail in well-regarded, science-based programs?</td>
</tr>
<tr>
<td><strong>Faculty and Staff</strong></td>
</tr>
<tr>
<td>• Does an adequate pool of highly qualified applicants exist when open positions occur? This consideration is of special importance for subspecialties.</td>
</tr>
<tr>
<td>• Are the numbers of capable faculty and staff sufficient to support high-quality programs for all degrees offered? If not, is there reasonable hope that the needed number of personnel can be soon added without impairing the quality of other essential departmental programs? (For departments offering graduate-level research degrees in food science, acceptable program quality cannot occur unless faculty numbers are well in excess of the minimum needed to teach required courses. Furthermore, high-quality education in research is not possible unless departmental research programs are strong, and these programs cannot be strong unless several faculty positions are filled on the basis primarily of research needs; faculty members who are expected to be major participants in research hold at least 50% appointments in research; and the number of research faculty is sufficient—perhaps six—to sustain a &quot;critical mass&quot;—perhaps 30—of graduate students in the department.)</td>
</tr>
<tr>
<td><strong>Students</strong></td>
</tr>
<tr>
<td>• Are the number of qualified students currently enrolled in the program (or likely to enroll in the program in the near future) sufficient so that all required undergraduate courses can be offered at least once a year, and all required graduate courses can be offered at least once every other year with enrollments of no less than 7-8 students per course?</td>
</tr>
<tr>
<td>• Are procedures in place to assure, with reasonable certainty, that entering graduate students possess capabilities consistent with those in well-regarded, science-based programs? (This is a point of great importance with regard to the quality of graduate programs in food science, since, in most situations, admittance to a department is tantamount to graduation.)</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
</tr>
<tr>
<td>• Are library materials and services sufficient to properly support the degree programs offered?</td>
</tr>
<tr>
<td>• Are facilities, equipment, and instrumentation sufficient to properly support the degree programs offered?</td>
</tr>
<tr>
<td>• Are budgeted departmental operating funds sufficient to properly support the degree programs offered (e.g., maintenance of departmental facilities, equipment, and instruments; payment of telephone and duplicating services, provision of adequate clerical support)?</td>
</tr>
<tr>
<td>• For departments offering graduate degrees, are research funds adequate in kind and amount to support projects that are suitable for educating graduate students in accordance with standards that generally apply in high-quality, science-based programs?</td>
</tr>
</tbody>
</table>
ficing program quality and detracting from efforts to establish a clear image of the capabilities possessed by individuals with degrees in food science.

5. Care must be exercised to assure that research projects for graduate students are consistent with generally accepted standards pertaining to graduate-level education in the biological and physical sciences. Projects that do not provide the student with substantial experience with experimental design, advanced methodologies and instrumental techniques, problem solving, and data analysis are of questionable suitability for thesis projects in food science.

6. The best teachers are generally those who are engaged in active research programs. In support of this contention, I quote from a presentation by Duane Acker, who at the time was associate dean of agriculture and director of resident instruction at Kansas State Univ. (Acker, 1964):

Research tends to keep the mind active and questioning. The process provides daily reminders that new knowledge continues to flow, that the mind must perceive, accept, integrate, adapt, and use this new knowledge. The real value of research to the teaching process is not the length of the publication list that develops, but the health and vigor of the mind it stimulates.

7. For those who carefully ponder the question, "What are the two most important determinants of success for students graduating in food science?" I believe many would choose "technical competence" and "personal attributes," but not necessarily in that order. "Technical competence" is meant to include problem-solving skills, and "personal attributes" includes personal motivation and skills in human relations. Some might question whether personal attributes deserves equal ranking with technical competence. I firmly believe that it does, in part because (1) it is my understanding that failure to advance in or retain a job is caused more frequently by deficiencies in personal attributes than by deficiencies in technical matters, and (2) a common complaint among senior industry personnel is that recently graduated food science students are lacking in communication skills (Bauman, 1979; Buchanan, 1972; Lauro, 1977).

If one accepts these factors as determinants of success, then a troubling realization becomes evident. Universities expend great effort, and generally succeed, in imparting technical com-
Educational Programs (continued)

petence, but they exert little effort and are notably unsuccessful in affecting personal attributes. This is not entirely the result of oversight, as some might conclude, but rather tacit recognition of the fact that the universities simply do not know how to alter the inner person (personality, motivation) in a consistently positive manner. This lack of effectiveness, I might add, extends to all other institutions, including, in many instances, the family. It is, of course, possible for universities to improve communication skills of graduates, but even this is not being done to the satisfaction of many employers. Cocurricular activities (internships in industry, involvement with student clubs, and the like) may help develop desirable personal attributes, but our present state of knowledge does not allow us to prove or disprove this possibility. Clearly, this problem deserves greater thought and discussion by planners of university curricula than it has received.

Guidelines for Assessing Program Quality

Surely, agreement must exist as to the need for continual evaluation and improvement of degree programs in food science. IFT, by means of several education conferences (Anonymous, 1962; 1977; Schaffner, 1958) and its Education Committee, has contributed greatly to this task at the undergraduate level. However, the time has come for an expansion of these effects at all degree levels.

I am not suggesting certification of degree programs, because I find the advantages with regard to upgrading weak programs insufficient to counterbalance the cost, bureaucratic burdens, and stifling of innovation that accompany certification programs. What I am advocating is the establishment of a set of guidelines that should encompass all degree programs (B.S. and above) and should include a broader range of educational issues in food science than have heretofore received serious attention at the national level. It is with some trepidation that I propose recommendations relating to this matter, since I don’t pretend to have a corner on all of the proper concepts. Nonetheless, I feel strongly that IFT must discuss these issues more actively, and I am hoping that what I am setting forth will stimulate this discussion and result in desirable actions.

The proposed guidelines, presented in Table 3, are self-explanatory and fairly general. I hope that some wise and knowledgeable group, such as the IFT Education Committee, will see fit to flesh out these guidelines with more-detailed recommendations, e.g., minimum student and faculty numbers for B.S., M.S., and Ph.D. programs, specific means of measuring program quality, etc.

I truly believe that food science is entering an exciting phase that will be dominated, academically, by improvements in program preparation rather than by growth in numbers. My sincere hope is that this article will stimulate discussion about issues in food science education and thereby help assure that IFT, during its second 50 years, will continue to exert strong leadership in this important aspect of our profession.

References


—Edited by Neil H. Mermelstein, Senior Associate Editor
A

t the 50th Anniversary of the Institute of Food Technologists, we properly look back to our begin­ning, and forward to tomorrow. This article will focus on some of the people who played key roles in the development of food science and technology and of IFT. They exemplify the Biblical quotation (Genesis VI, 4), “There were giants in the earth in those days ... mighty men which were of old, men of renown.”

There are difficulties and risks in doing this. There were 832 founder or charter members (Collins, 1989), and not all of those who deserve to be mentioned were among them. This brief review will mention some in passing, and a mere ten in some detail. Inevitably, this becomes an act of bias, an accident of acquaintance, or the result of a woefully incomplete education on my part. Food science and technology forms too complex and detailed a fabric to be woven from so few threads.

Rather than a history, then, this is a collection of vignettes with a central theme—that food science and technology, and IFT, have succeeded because they filled a need. Their founders, their teachers before them, and their students since, brought talents, knowledge, and insights appropriate to the times. Those we honor here brought science and system to what had been art and invention. If this useful role is to continue, food science and technology, and its practitioners, must continue to supply what the present and the future require.

The Gradual Evolution of the Field

Food science and technology did not suddenly appear. It was no Athena, emerging mature and fully armed from the head of Zeus, although it did, in fact, result from many headaches. Food science and technology did not so much emerge as evolve, with the technology preceding the science.

This discussion focuses on four periods: the pre-industrial era, prior to 1795; the industrial, dawn-of-science era, 1795-1894; the age of nutrition and the beginning of food science, 1895-1938; and the early years, 1939-1955. The rationale for these dates is that 1795 is when Nicolas Appert began his experiments on canning; 1895 is when Prescott and Underwood began their historic work that brought canning under scientific control; and 1939 is when IFT was founded. I end the “early years” at about 1955, an arbitrary date for the purposes of this article.

Even where the written record is largely blank, we can be sure that the earliest beginnings stemmed from home food preparation’s being precariously—and sometimes dangerously—adapted to commerce.

Originally, the only difference between the kitchen and the factory was one of scale and purpose. The original food technologists were the nameless discoverers, inventors, and improvers of cheesemaking, winemaking, beer brewing, sun drying, salting, and smoking. That was art. Later, invention improved upon art. Later still, science improved on invention, with enormous gains to human health and safety, and to the provision of a safe, nutritious, varied, and economical food supply. In this process, food science and technology evolved—first out of chemistry, then out of microbiology and medicine. Still later, biochemistry, nutri­

Some of the people who played key roles in the development of food science and technology and of IFT ... exemplify the Biblical quotation ... “There were giants in the earth in those days ... mighty men which were of old, men of renown.”

The author, 1971-72 President of the Institute of Food Technologists, is Consultant, 7004 Wellington Ct., Baltimore, MD 21212

The author, 1971-72 President of the Institute of Food Technologists, is Consultant, 7004 Wellington Ct., Baltimore, MD 21212
Kolbe and Ira Remson. He was also an entrepreneur. He invented the first patented food, Liebig’s Meat Extract, and thereon founded a large and profitable industry (Anonymous, 1908). His application of quantitative analysis to foods and soils led directly to transforming nutrition and agriculture from art and folklore into science.

Perhaps the greatest of these “early moderns” was another chemist, Louis Pasteur. His interest in fermentation led to research on the production of alcohol, vinegar, wines, and beer, and the souring of milk. He developed pasteurization—the process of heating milk and milk products to destroy food-spoilage and disease-producing organisms. In breaking these paths that led to modern food science and technology, Pasteur the chemist became the father of bacteriology and of much of modern preventive medicine.

I often worry that we weary our readers and listeners by tiresome repetition of that octasyllabic phrase “food science and technology.” Thus, the following quote from Pasteur has great appeal for me: “No, a thousand times no; there does not exist a category of science to which one can give the name applied science. There are science and the applications of science, bound together as the fruit to the tree which bears it” (Pasteur, 1871). Under the protection of Pasteur, I will usually, hereafter, refer only to “food science,” but I will mean both the tree and its fruit.

The productive lives of these four pioneers cover all but the last few years of the 19th century. Their discoveries made later progress possible, progress that became constantly more interdisciplinary and international in scope. The period on which we now focus is the third period, the 44 years from 1895 through 1938.

Food science and technology, and IFT, have succeeded because they filled a need. Their founders, their teachers before them, and their students since, brought talents, knowledge, and insights appropriate to the times.

The Beginning of Food Science

At the beginning of that period, vitamins were unknown; the earlier term “vitamines” was not coined by Funk until 1912. The work of Pasteur and others had led to the recognition of the existence of enzymes, but the term “enzyme” had been suggested by Roberts only 14 years earlier (Anonymous, 1971). The word then meant “an unorganized ferment.” Scientists were just beginning to realize that when food made people sick, it was often due to contamination by specific microorganisms, most of them not yet identified.

During those 44 years, the role of the essential amino acids was discovered and described. All of the vitamins except vitamin B-12 were discovered and named. We learned how to prevent rickets and pellagra, goiter and beri-beri. That was incredible progress, even though in 1939 there were in every community a few who bore silent
but visible testimony that this knowledge was recent, and incompletely implemented.

Our knowledge of foodborne illness in 1939 was largely restricted to botulism, staphylococcal infections, and salmonellosis, but systematic—if grossly incomplete—reporting of foodborne illness outbreaks was routine.

Canning was reduced to a technology firmly under scientific control. By 1939, the use of refrigeration in the transport and storage of perishable food became widespread, and frozen foods had begun to reach the retail level. There were roadblocks, however. Home refrigerators had replaced the icebox, but their freezers held only four ice-cube trays. A popular venture capital business was installing neighborhood frozen-food-locker centers where you could conveniently keep your frozen foods only a few blocks away. Except for the recent and incomplete entry of frozen foods, there was no fresh seafood more than a hundred miles from the coast. Dried and salted was the rule. Lent was hell. Fresh oranges and lemons, apples, cabbage, and turnips were common, but most other fruits and vegetables were available fresh only when locally in season, and you enjoyed them when you could.

All of this was in the traditional, conservative, slowly moving food business. Put this against the background of rapid advances in transportation—the automobile and the airplane—and in communication—the radio, with television just around the corner—and one can begin to recapture that giddy feeling that material progress was unstoppable. There were no cynical snickers at the DuPont slogan, "Better things for better living through chemistry."

But there were enormous problems. The Great Depression was 10 years old—and continuing. American agriculture had been in a slump since 1920. The Dust Bowl had recently added to the misery, and John Steinbeck's *Grapes of Wrath* simply reflected a reality many of us remember all too well. Moreover, though some chose to ignore it, most of us realized that the world stood at the brink of war.

Key Individuals: The First Generation

The remainder of this article will treat briefly—indeed, all too superficially—ten of the key figures in this period and in IFT’s early years, and their roles in bringing contributions from other sciences that have shaped the field of food science that we know today.

My choice of these ten individuals results from several criteria. First, they must have played a key role in setting future direction for food science. Second, applicable to all but two, they must have had significant activity within IFT. Third, they must have made significant contributions in the third and fourth periods, between 1895 and 1955. Unfortunately, a fourth criterion was availability of information about these individuals. Nevertheless, the choice is inevitably arbitrary, and other individuals and their contributions would have served—and deserved—as well. These individuals succeeded because they met effectively the needs of the times just described.

- **Samuel Cate Prescott** is the only possible choice for the first of the ten trailblazers. Pioneer food scientist and first president of IFT, Prescott was born in rural New Hampshire in 1872. He received his bachelor’s degree in chemistry from Massachusetts Institute of Technology in 1894 and worked briefly as a bacteriologist and assistant chemist at the sewage purification plant in Worcester, Mass. In 1895 he returned to MIT and began, with William Lyman Underwood, the research on canning that transformed that industry from pragmatic practice "into a technology under scientific control" (Goldblith, 1981).

The research on the scientific basis of canning technology was pivotal for many reasons beyond the safety of the process. It established a precedent of fruitful collaboration with industry. It led Prescott to develop the first course in "industrial biology." It led him in a direction parallel to Pasteur to integrate biology and chemistry, and this reinforced the growth of biochemistry and nutrition. Industrial biology applied the growing knowledge of bacteriology to food and beverage production and, most important, to the dairy industry.

Prescott had learned the principles of sanitation as an undergraduate from Ellen Swallow Richards and William Thompson Sedgwick. Richards was MIT’s first female graduate, class of 1873. She was an instructor and gave a course in sanitary chemistry (note that almost everything was "chemistry" in those days). Sedgwick was MIT’s first professor of biology. Thus began Prescott’s lifelong interest in sanitation. He was a leader in the sanitary milk crusade and in the pasteurization of milk, and served as a major in the Army Sanitary Corps during World War I.

Prescott’s interests continually widened: they extended to food dehydration, refrigeration, food additives, and the complex chemical composition of foods such as coffee. One of his most valuable contributions was breaking down the barriers between the basic sciences—barriers that hindered the development of interdisciplinary fields such as food science.

Beyond all this, Prescott was an able administrator. He was Dean of the School of Science at MIT from 1932 to 1942. He played a key role in organizing the first two Food Technology Conferences at MIT in 1937 and 1939. At the latter conference IFT was founded, and Prescott served as its first president (1939–41).

Last, and perhaps most important of all, a great teacher is known by his students and coworkers. Prescott’s included Bernard Proctor, another of our ten pioneers. Prescott died in 1962, but his name lives on in IFT’s Samuel Cate Prescott Award for research.

- **Edwin Bret Hart**, pioneer nutritionist, was born in 1874, two years after Prescott. He obtained a B.S. degree in chemistry from the University of Michigan in 1897, worked at the New York State Experiment Station in Geneva, studied under the biochemist Kossel at Marburg and Heidelberg in 1900 and 1901, and then returned to Geneva. In 1906 he moved to the College of Agriculture at the University of Wisconsin, attracted in part by the presence there of the man who would become his mentor and elder coworker, Stephen M. Babcock.

At that time, prevailing opinion held that adequate diet for farm animals, and, by implication, for man, could be defined by gross chemical analysis alone—by specifying how many calories and how much protein, carbohydrate, fat, and minerals (ash) a diet should contain. At Wisconsin, Hart soon came to share Babcock’s skepticism that an adequate diet could be defined so simply.
In a now-classical “single-grain” experiment, four groups of heifers were raised and bred on diets differing in grain source but equal in calories, protein, carbohydrate, fat, and ash. One group received a wheat diet, another oats, a third corn, and the fourth a blend of the three. Those on the corn and the blended diets thrived and bred successfully. Those on oats did poorly, and those on wheat worst of all. The work was laborious, but the results were spectacular. Fortunately, Cruess' persistence and economic good sense prevailed.

From his own farm days, Cruess brought to food technology a firm practical orientation, but he supported it with solid basic science. This was notable particularly in the colleagues he chose to staff what became one of the world's leading departments, of which he was head from 1938 to 1954. Cruess was a superb teacher, memorialized in IFT's Wm. V. Cruess Award for teaching. Among his students were Emil Mrak, C.O. Chichester, Maynard Joslyn, and George Marsh.

Cruess was president of IFT in 1943-44. He died in 1968.

- Clarence Birdseye deserves inclusion because of his own contributions to the development of frozen foods, and because he epitomizes the transition from dependence on invention to dependence on science. He was the shrewd inventor who transformed chance observation into successful industrial practice. He is the outstanding technical entrepreneur on my list; more than anyone else, he helped to create the frozen food industry, and his name is still on our food packages. And he was a master of timing: he and his partners sold their frozen food business to the Postum Co.—soon to become General Foods—for $22 million just four months before the 1929 stock market crash.

Birdseye was born in 1886 and graduated from Amherst College in 1910. He was a fur trader in Labrador in 1912-17. During that time, he noticed that when he caught fish through the ice in the Arctic winter, they froze immediately in the cold air. More remarkably, when the fish were thawed and cooked, the texture and flavor were as good as with fresh fish. He also noted with disapproval, as did Carl Fellers later, the exceedingly poor and insanitary handling practices characteristic of the commercial fishing industry of that day. In 1923, recalling those observations, he began to experiment with mechanical methods of quick freezing as a means of capturing the potential quality otherwise quickly and carelessly lost. He devised several methods, including continuous double-belt and multplate freezers.

Marketing was more of a problem, due to lack of trade knowledge and interest, lack of adequate frozen storage in retail stores, and consumer resistance. Until Birdseye’s innovations, “cold storage foods” were slowly frozen, and deserved the poor reputation they had. Surmounting these obstacles required 15 years of patient and ingenious marketing effort, much of it after the General Foods acquisition, but by 1939 substantial retail market penetration had been achieved.

Birdseye obtained more than 300 patents. While not
himself a food technologist or IFT member, he worked closely with some of the great ones, including Donald Tressler, Clifford Evers, and Ken Dykstra. He died in 1956.

- Carl R. Fellers, one of the most intensely energetic of our early leaders, was born in Hastings, N.Y., in 1893. He received his A.B. degree from Cornell University in 1915, his M.S. from Rutgers University in 1916, and his Ph.D. from Rutgers a year later. He moved through a rapid succession of posts, including one with the National Canners Association (1921-24) as it was beginning its definitive work that assured the present high level of safety of canned foods. In 1926, he moved to Massachusetts Agricultural College (now the University of Massachusetts), where he remained.

Once the safety of canned foods was assured, Fellers shared with many early food scientists a strong interest in the nutritional quality of canned and other processed foods. This took on added significance in the late 1920s and '30s as we learned the identity of specific vitamins and minerals.

Fellers had an early interest in improving seafood processing, and in 1953, after many frustrating delays, he persuaded a reluctant legislature and an even more backward industry to fund and support, as a part of the university, a Fisheries School and Laboratory, the second in the country.

He invented methods for pasteurizing dried fruits and canning Atlantic crab. His interest in maintaining quality in frozen and canned foods led him to introduce the use of ascorbic acid as an antioxidant. He initiated the fortification of apple juice, and, in work parallel to that of Cruess, led the cranberry growers to use what had been fresh-market culls in producing the cranberry juices and other processed products that are now so popular.

He was a restless, dynamic teacher and department head, immensely loyal to his students, among whom are such familiar names as Edward Anderson, Guy Livingston, Kirby Hayes, Jack Francis, John Powers, and Ray Morse, the last three of whom have been president of IFT. He was a founder of IFT and served as president in 1949-50. He died in 1960.

Key Individuals: The Second Generation

Except for Birdseye, our first five pioneers above began in a narrow basic discipline, usually chemistry. As they shaped what is now food science, they broadened their scope, making both themselves and the field interdisciplinary. Our second generation began with this already interdisciplinary background.

- Bernard E. Proctor, a student of Prescott’s, was born in 1901, graduated from MIT in 1923, and received his Ph.D. there in 1927. He stayed on as an instructor in food technology, and rose steadily to become a full professor in 1944 and department head in 1952.

One of his initial research interests was food microbiology, and this led him eventually in two novel directions. He published a series of four papers on the microbiology of the upper atmosphere. Later, in the late 40s and early 50s, he became one of the earliest to study the use of ionizing radiation for the preservation of food. He took an early and badly needed interest in the sanitation of frozen foods. Research needs inspired by World War II led him to investigate the compression of dehydrated foods, and to solid scientific investigation of effective food packaging, particularly for unusual environments.

Proctor was exceedingly effective and respected for meeting the needs of the times. He was consultant on foods to the Secretary of War, and Director of Subsistence and Packaging Research and Development in the Office of the Quartermaster General. He was member or chairman of several National Research Council committees and a member of the United States delegation to the United Nations conference in Geneva on the peaceful uses of atomic energy. He was a superb teacher, a founding member of IFT, and president of IFT in 1952-53. He died in 1959.

- Emil Marcel Mrak was born in San Francisco in 1901, and received all his degrees from the University of California at Berkeley, from his B.S. in food technology in 1926 to his Ph.D. in botany and mycology in 1936, by which time he had written or coauthored almost 40 papers. His rise thereafter was rapid: instructor in 1937 and full professor and chairman of the department of food technology in 1948. He continued and expanded the tradition of excellence begun by Cruess, particularly after the move of the department to Davis in 1951.

Mrak always maintained his basic research interests, particularly those relating to the classification of yeasts; two species are named after him. He was a candid, friendly, and challenging teacher. His broad interests were expressed in several ways, among them editing and contributing to the series of books called Advances in Food Research. He was an outstanding administrator, approachable, thoughtful, decisive, and clear in communication. He became Chancellor of the Davis campus in 1959, and presided over it during the period of its greatest growth.

Always active internationally, he was cofounder and first president of the International Committee of Food Science and Technology, predecessor to the International Union of Food Science and Technology. After he retired from Davis in 1969, his public-service role as advisor, panel member, or chairman simply increased. He was articulate and an engaging way that never left his listener in doubt of his views. Even beyond Prescott and Proctor, Mrak brought the perspectives of food science into the highest levels of government and industry. Of our ten early leaders, he is the first I knew not just as a distant eminence, but as a warm personal friend. He was IFT president in 1957-58, and died in 1987.

- Bernard L. Oser, a biochemist, is noteworthy because he brought to the development of food science, at the right time, needed knowledge and insights from two related areas, nutrition and toxicology. Oser received his B.S. degree from the University of Pennsylvania in 1920 and his Ph.D. from Fordham University in 1927. Between those years, he worked as a physiological chemist at Jefferson Medical College and as a biochemist at Philadelphia General Hospital before joining Food and Drug Research Laboratories (FDRL) in 1926. He became president of that organization, and held that position until his retirement in 1976.

As the identification of the vitamins proceeded, the need increased, in both research and commerce, to measure their levels in food and drug products, as well as in body

These giants . . . met the needs of their times. They brought science and understanding, quantification and system, to what had been art and invention.
tissues and fluids. Investigators early noted that bioassays, using test animals, very often gave results different from in vitro "chemical" tests. Pursuing these differences led to the concepts of bioavailability, ingredient interactions, absorption and excretion rates, and the urgent importance of specifications so that one knows with precision what one is testing. In all of this, Oser was a pioneer. He also was one of the first to press the need for examining the effects of exogenous substances on reproduction.

As concern over food additives grew in the 1950s, Oser took an increasing and effective role in educating the food industry to meet new requirements for toxicological studies and safety evaluation. Virtually before anyone else, he recognized the uselessness of rigid concepts, such as "zero residue." He has been an effective spokesman for sanity in the frequently shrill debates on food safety.

His background in physiological chemistry and his association in his graduate work and at FDRL with Philip Hawk led to his editing, over many years, Hawk's Physiological Chemistry, now in its 14th edition.

Oser has repeatedly served on the FAO/WHO Joint Expert Committee on Food Additives and on committees of the National Research Council. He is a founding member of IFT and served as its president in 1960-61. I am proud to add that he is also my professional "uncle," mentor, frequent coauthor, and friend.

- Loren B. Sjöström, known to his many friends as "Johnnie," was born in 1912, received his B.S. degree from Northeastern University in 1935, and joined the consulting firm of Arthur D. Little (ADL) in 1936. He rose to become vice-president of ADL from 1962 until his retirement in 1977.

Prior to 1939, there were expert tea, coffee, and wine tasters, flavorists, and perfumers. They and board chairmen and presidents—not to mention the wives of board chairmen and presidents—made the decisions that determined how the foods we ate and the articles we used tasted and smelled. But that was art, or business judgment, not science. Some of the individual experts were capable of incredible feats of detection, discrimination, and creativity, but no one else could readily reproduce or understand them—indeed, Heaven forbid that anyone should! As the food-processing and related industries grew, individual experts retained an essential but more limited role, but a more available, more understandable system became urgently needed. Sensory analysis began its hesitating development.

Organized, large-scale, scientifically focused activity in the field of sensory analysis is considerably younger than IFT. Very little other than that described here and a few early attempts at measuring consumer acceptance occurred before 1955.

Sjöström began his work under the legendary Ernest C. Crocker. Under Sjöström’s leadership, ADL developed a flavor laboratory. This was unusual for a consulting firm to do, and remarkable at the time for being based on a scientific and descriptive approach using trained groups rather than a highly trained individual expert.

With Stanley Cairncross, Sjöström developed the flavor profile method for descriptive testing of food, beverages, and similar products. Their first paper (Cairncross and Sjöström, 1950) was presented at the IFT Annual Meeting in 1949. The method emerged from a project, begun in 1946, testing the effect of MSG on food flavors. It was a pioneering method and is still used on hundreds of products in hundreds of locations.

Not only academicians are known by the coworkers they find and bring forward—another sensory evaluation pioneer, Jean Caul, is a "graduate" of Cairncross and Sjöström’s flavor laboratory.

Sjöström has also been active in IFT and a frequent author in its journals.

- Amihud Kramer also made his contribution by bringing to food science needed skills and insights from another field—mathematics, specifically statistics. Kramer was born in 1913 in Austria–Hungary. After coming to this country, he obtained all of his higher education at the University of Maryland—B.S. degree in 1938, M.S. in 1939, and Ph.D. in 1942. From 1941 to 1944, he worked at the National Canners Association on developing objective methods for measuring the quality of canned foods, and on an NRC project for revising nutrient tables that eventually led to the U.S. Dept. of Agriculture’s Handbook No. 8. He returned to the University of Maryland, becoming an associate professor in 1948 and a professor in 1949, and retiring in 1980.

Kramer was a leader and prime mover in the development of statistical quality control and of operations research and systems analysis applied to the food industry. His books, particularly Quality Control for the Food Industry (Kramer and Twigg, 1970, 1973), and his courses were enormously influential in helping industry meet the increasing quality and cost requirements it faced. He contributed a new method for determining the significance of differences in multiple comparisons in sensory analysis. He was active nationally and abroad in devising procedures for providing optimal solutions for production of desirable nutritional and sensory quality at acceptable cost.

Kramer was cofounder and past chairman of IFT’s Quality Assurance and Refrigerated and Frozen Food Divisions, and was an IFT Regional Communicator. He was exceedingly active in advisory groups and committees here and abroad. His unexpected death at age 68 occurred while he was doing something else he also enjoyed—playing tennis.

- Other Individuals. Our set of pioneers really does not end here. Even within the stated time period, many others are worthy of our gratitude. Among them are Fred Tanner, George Stewart, Maynard Amerine, Fred Blanck, C. Olin Ball, Maynard Joslyn, Charles Townsend, Donald Tressler, Philip Bates, David Peryam, John Jackson, Victor Conquest, E.J. Cameron, and Samuel Goldblith. Beyond them, again to mention only a few, the names of J.R. Vickery in...
Different Times, Different Needs

These giants, whose careers I have so quickly reviewed, met the needs of their times. They brought science and understanding, quantification and system, to what had been art and invention. As they dealt with food problems, they applied their knowledge of microbiology, nutrition, biochemistry, irradiation physics, toxicology, sensory analysis, and statistics. In so doing, they, and others, created the food science we know today. They dealt with a public that was well aware of material progress and of the role of science in that progress. Our pioneers worked at a time when America was becoming a single national market and a world power. They applied their knowledge where needed in time of global war, and to domestic and international development in time of peace.

We now face different times and different needs. It is appropriate to mark some of the differences between the times of our pioneers, and now, and in the future.

Then, as today, the major real problems in food safety were microbiological, but then they were on the farm or in the factory—tubercular dairy herds, tainted meat, poorly processed canned goods. Now, the risks, though smaller, have shifted to the point of preparation in the home and the foodservice facility.

Then, the major nutritional risks were the deficiency diseases, even in the more developed world. Now, some of these, such as vitamin A deficiency, still persist pervasively in the developing world, along with simply too little food; but in the developed world, the predominant risks are overconsumption and the still-unsettled role of diet and nutrition in chronic disease. It is in these areas, I suspect, that the next great advances in nutrition will come. There is strong indication that when they do, they will require some substantial changes from traditional food composition and preparation. And then the next great challenge to food science will arise. Those new foods required by these changes will need to be highly acceptable, economically available, and varied to suit our genetically diverse human species.

The last contrast is the most challenging. Then, the public accepted enthusiastically the promise of science. Today, even with much of that promise visibly fulfilled, the failures, flaws, and excesses—worse yet, the purely imaginary risks—have impressed many far more than the progress gained, the promises fulfilled. We see the result in fear, rejection, mysticism, and faddism, much of it promoted by fraud. Moreover, every real advance of science places it that much ahead of lagging public understanding. These challenges to more effective education in science and better communication of science are as intimidating as those to the progress of science itself.

This is sobering, but it should not be a discouraging prospect. Life expectancy is increasing. Death rates are not going up but are steady or declining. We have dealt with many once-major health threats, and we are closer than ever to being able to deal effectively with those we now face. For this, and particularly for those benefits that have come to us through the food supply, we owe much to the individuals whose work we have discussed. In the genesis of IFT, there truly were "giants in the earth . . . men of renown." Today, to meet new needs, we must see further still. And if, to paraphrase Albert Einstein, we succeed in seeing somewhat further than they, it is because we stand on the shoulders of giants.

References

Pasteur, L. 1871. Why France has not found superior men in the moment of peril. Revue Scientifique.

Based on the celebratory presentation at the 50th Anniversary Annual Meeting of the Institute of Food Technologists, Chicago, III., June 25–29, 1989.

Beyond the sources specifically referenced, the author is greatly indebted to the following for a rich store of background information that could only be used in small part: A.S. Clausi of General Foods (retired); Owen Fennema and Richard D. Powers of the University of Wisconsin; F.J. Francis of the University of Massachusetts; Samuel A. Goldblith of Massachusetts Institute of Technology; John Hawthorn of the University of Strathclyde; Anne J. Nielsen of Arthur D. Little, Inc.; B.S. Schweigert and Carol Cooper of the University of California at Davis; A.J. Siedler of the University of Illinois; and Neil H. Mermelstein of IFT.

—Edited by Neil H. Mermelstein, Senior Associate Editor
Food Biotechnology: Yesterday, Today, and Tomorrow

Susan Harlander

Biotechnology is the buzzword of the 1980s. Fundamental discoveries in molecular biology in the '60s and '70s initiated a biological revolution which has "the potential to change the technology paradigm of our present society far more than the industrial revolution, to transform the world's workplaces and to enormously enhance the quality of human lives" (Schneiderman, 1986). This is the promise of biotechnology!

Every industrial sector, including agriculture and food processing, is attempting to assess the potential impact of this revolutionary science on its business. This article will explore the potential implications of biotechnology for the food processing industry. It will include a brief history of this revolutionary new science, a discussion of research currently in progress, and a look at how food biotechnology could be used in the next 50 years to meet the demands of the consumer-driven marketplace.

Yesterday

Despite all of the media hype relative to biotechnology, confusion remains as to what biotechnology actually is. The word biotechnology is derived from "bio," meaning life or living systems, and "technology," defined as a scientific method for achieving a practical purpose. Biotechnology is broadly defined as the collection of technologies that employ biological or living systems of plant, animal, or microbial origin, or specific compounds derived from these systems, for the production of industrial goods and services.

Biotechnology is not new to the agricultural and food sector. Man has been exploiting living systems for the production of food for centuries. The staggering pace of new discoveries in molecular biology has stimulated industrial sectors, including the food processing industry, to evaluate the potential technological and economic impact of biotechnology on their businesses.

The author is Assistant Professor, Dept. of Food Science and Nutrition, University of Minnesota, St. Paul, MN 55108

Food Biotechnology is not new to the agricultural and food sector. Man has been exploiting living systems for the production of food for centuries.

Although grounded in the traditional, "modern" biotechnology has a relatively brief history (Fig. 1). It began with the elucidation of the structure of DNA in 1953 by Watson and Crick, which was followed by a rapid expansion of our knowledge of the function and organization of this molecule. This discovery of restriction enzymes in the early 1970s heralded a new era in biology, with the central focus on the molecular basis of living systems. There has been an explosion of research activity in the public, academic, and private sectors, and the future of this technology is limited only by our imaginations.

One of the most significant technologies to emerge from the 1970s was recombinant DNA technology or genetic engineering (Fig. 2). Gene cloning allows the transfer of DNA across natural species barriers in a precise, controllable, nonrandom, and timely manner. DNA, the universal code of life, is structurally and functionally identical in all living organisms. Therefore, the basic principles of genetic engineering apply to all living organisms, although the specific vector and gene-transfer systems vary depending on the host organism to be engineered.

The first commercially available genetically engineered product, human insulin, was approved for use in 1982. To date, the major industrial focus of biotechnology has been its use in the development of human health-care products, diagnostic tools, and vaccines. Many of these products, including human growth hormone, alpha interferon, and tissue plasminogen activator, are high-value therapeutic drugs which are commercially available and approved for use by the Food and Drug Administration. Scores of other products are in phase II or phase III clinical trials. The staggering pace of new discoveries in molecular biology, coupled with commercial outgrowth of these emerging technologies, has stimulated additional industrial sectors,
including the food processing industry, to evaluate the potential technological and economic impact of biotechnology on their businesses.

**Today**

The food chain begins with the planted seed (production agriculture) and ends with the consumption of products by consumers (utilization end of the food system). Other than fruits and vegetables, which are often consumed in the fresh or raw state, most food products are processed to some extent. The food processing industry is the link between the products of the farm and the consumer; it transforms relatively bulky and perishable raw agricultural products into shelf-stable, convenient, and palatable foods and beverages.

Application of biotechnology to the food processing industry requires cooperation among a number of different scientific disciplines (Fig. 3). Although economics is an important factor for applying biotechnology in every industrial sector, it is a critical factor in the food industry, which operates with a much smaller profit margin than many other industries. A number of applications of biotechnology currently under development provide a glimpse of what is currently happening in the food biotechnology arena:

- **Production Agriculture.** The first impact of biotechnology on the food chain has been in the production agriculture sector. The primary focus of agricultural biotechnology is improvement of the yield of plant products at the farm level. There are numerous examples of disease-resistant (Hall, 1987), herbicide-tolerant (Shah et al., 1986),
Food Biotechnology (continued)

and insect- or virus-resistant (Fischhoff et al., 1987; Cuozzo et al., 1988) plant varieties developed via selection in tissue culture or by genetic engineering techniques. These same methods have been used to develop salt-tolerant, temperature-tolerant, or drought-resistant crops, thereby extending the amount of land which can be used for food production. Microbial pesticides such as the insecticidal protein from Bacillus thuringiensis (Dulmage, 1981) offer a viable alternative to chemical control, and the use of genetically modified Rhizobium species with enhanced ability to fix nitrogen may decrease our dependence on nitrogen-based fertilizers (Okon and Hadar, 1987). The ultimate goal of such research is to increase the efficiency of agricultural production.

To meet consumer demands and keep pace in an increasingly competitive global marketplace, the U.S. food processing industry will need to enlist every available resource, including biotechnology.

- Custom-Designed Raw Ingredients. Raw agricultural products are often viewed by the food industry as generic commodities, and the processor has little choice but to process what is available, modifying the manufacturing parameters to compensate for inconsistencies in raw ingredients. Recent advances in plant tissue culture technology, genetic engineering, and antisense RNA and DNA technology (Roberts, 1988) offer the potential to custom design raw commodities possessing predetermined traits which provide added value for the processor, such as improved nutritional, functional or processing characteristics. Some examples are provided in Table 1.

- Plant Cell Suspension Cultures. Tissue can be excised from the root, stem, leaf, or fruit of plants, and the undifferentiated cells can be propagated in solid or liquid media containing all of the essential nutrients required for growth. Plant cell culture for production of natural food ingredients offers several distinct advantages over extraction of these components from plants. Seasonal variations, unfavorable weather conditions, and epidemic diseases are not problems when plant tissue is grown under well-defined and controllable laboratory conditions. Because many of the plant-derived specialty ingredients of interest must be purchased from foreign countries, food processors must deal with an erratic supply caused by natural or political calamities in these countries. In addition, they have little control over how the plants are grown, harvested, transported, or stored. Plant cell culture allows the processor to control the quality, availability, and processing consistency of the ingredients.

Examples of high-value food ingredients which could be produced by plant cell suspension culture include colors (betalaines, anthocyanins, saffron) and flavors (vanillin, capsacin). These compounds are secondary metabolites in plant cells; therefore, current technology is focusing on uncoupling secondary metabolite production from cell differentiation so that these compounds could be produced economically by plant cell suspension cultures. Ruyter and Stockigt (1989) have compiled a list of about 80 new cell culture-associated, low-molecular-weight compounds which are not found in differentiated plants. Cell culture may serve as the source of many previously unidentified...
Fig. 2—Schematic of Genetic Engineering. DNA can be isolated from any living organism (plant, animal, or microbial), digested with restriction enzymes, and inserted into a plasmid vector. The recombinant DNA molecules are transformed into bacterial cells which can be grown to produce large quantities of the cloned gene product.

Fig. 3—Scientific Disciplines involved in food biotechnology.

substances that have unique properties in foods.

- Enzymology. The food processing industry is the largest user of enzymes, accounting for more than 50% of world enzyme sales of $445 million in 1987 (Connor, 1988). Most of the enzymes approved for use in foods are derived from generally recognized as safe (GRAS) microorganisms, plants, or animals. Rennet, the enzyme extracted from the forestomach of calves and used in the manufacture of cheese, is the first example of a genetically engineered enzyme to be used in food. The gene which codes for the enzyme has been cloned into a strain of Escherichia coli, and it is now possible to obtain large quantities of pure enzyme via fermentation. Recombinant rennet is currently under review by FDA.

Genetic engineering techniques such as site-specific mutagenesis have been used to specifically alter the primary amino acid sequence of enzymes (Wetzel, 1986). The result is an engineered protein with altered, and sometimes enhanced, properties. Examples of how this technology has been used to improve enzymes used in food processing are provided in Table 2.

- Genetic Improvement of Food Fermentation Microorganisms. Microorganisms have been used for centuries for the production of fermented foods such as cheese, sausage, sauerkraut, wine, and bread. Genetic engineering provides an alternative to classical mutation and selection for improving microbial starter cultures. To date, primary emphasis has been placed on construction of multifunctional food-grade cloning and expression vectors and development of high-efficiency gene-transfer systems. The ultimate goal is to construct strains with improved metabolic properties.

Genetically engineered starter cultures are not yet commercially available; however, some examples of how genetic engineering could be used to improve organisms for various fermentation processes are provided in Table 3. Availability of such strains would have an impact on several aspects of fermentation, including production economics,
Food Biotechnology (continued)

shelf life, safety, nutritional content, consumer acceptance, and waste management.

- **Natural Ingredients.** Consumer concern regarding chemical additives in foods and consumer demand for "natural" products have resulted in demand for microbial metabolites which can be used as natural ingredients in foods. A number of food ingredients are already being produced by microorganisms (Table 4). Other products of interest include flavors, enzymes, biopolymers, surfactants, noncaloric sweeteners and fat substitutes, antioxidants, and natural preservatives. The primary emphasis to date has been on the use of microbial isolates found in nature; however, genetic engineering of food-grade organisms is also being investigated.

- **Animal Biotechnology.** Growth-hormone genes from several animal species have been isolated and characterized. When injected into dairy cows, bovine somatotropin (BST) has been demonstrated to increase milk production and feed efficiency, and accelerate the growth rate (Hart et al., 1985). The porcine equivalent, PST, has the ability to dramatically alter carcass composition, significantly decreasing the amount of fat and increasing the amount of protein. Meat from PST-treated animals is leaner than meat from untreated animals and might be more desirable to health-conscious consumers. BST and PST are currently under review by FDA. Growth hormones from other animals, including fish and chicken, are also being investigated. These applications will have a profound impact on the efficiency and profitability of animal agriculture, and will have an indirect impact on the food industry.

- **Diagnostic Tools and Rapid Detection Methods.** With recent consumer concern over the safety of the food supply, the food industry is in need of improved methods for detecting foodborne pathogens, toxins, and chemical contaminants in raw ingredients and finished products. Rapid and sensitive methods based on the development of DNA probes and poly- and monoclonal antibodies have begun to replace classical microbiological techniques for detection of potentially pathogenic microorganisms (Fitts, 1985; Flowers et al., 1988). Kits are currently available for detection of two of the main culprits of concern, Salmonella typhimurium and Listeria monocytogenes.

An emerging technology which will dramatically improve the sensitivity of DNA probe-based assay systems, polymerase chain reaction, allows for the amplification of DNA sequences (Kazazian and Dowling, 1988). In the near future, it may be possible to detect a single contaminating microorganism in a food product. Some examples of foodborne pathogens for which DNA probes are currently under development are given in Table 5. Development of

<table>
<thead>
<tr>
<th>Crop</th>
<th>Characteristics</th>
<th>Impact on processing</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Increased solids content absence of the enzyme polygalacturonase</td>
<td>Decreased cost for transport, less water to remove during processing</td>
<td>Lewis (1986)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longer shelf life, vine-ripened flavor, decreased need for refrigeration during transport</td>
<td>Roberts (1988)</td>
</tr>
<tr>
<td>Corn</td>
<td>Increased level of specific amino acids</td>
<td>Enhanced nutritional quality</td>
<td>Hibberd et al. (1985)</td>
</tr>
<tr>
<td>Rape</td>
<td>Decreased level of saturated fatty acids</td>
<td>Enhanced nutritional quality</td>
<td>Knauf (1986)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Application</th>
<th>Useful improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha-amylase</td>
<td>Starch liquefaction</td>
<td>Acid-tolerant and thermostable</td>
</tr>
<tr>
<td>Amyloglucosidase</td>
<td>Production of high-fructose corn syrup</td>
<td>Immobilized with higher productivity</td>
</tr>
<tr>
<td>Esterases, lipases, proteases, etc.</td>
<td>Flavor development</td>
<td>More specificity</td>
</tr>
<tr>
<td>Glucose isomerase</td>
<td>Production of high-fructose corn syrup</td>
<td>Increased thermostability</td>
</tr>
<tr>
<td>Limoninase</td>
<td>Debittering of fruit juices</td>
<td>More complete limonin degradation</td>
</tr>
<tr>
<td>Protease</td>
<td>Beer chill-proofing</td>
<td>More specificity</td>
</tr>
<tr>
<td>Pullulanase</td>
<td>Production of high-fructose corn syrup</td>
<td>Thermostability</td>
</tr>
</tbody>
</table>
rapid methods will dramatically change the way quality control and quality assurance are conducted in the food industry.

- Waste Management and Value-Added Technology. Environmental concerns and economic issues necessitate better utilization of raw materials and reduction of waste generated by the food processing industry. Innovative methods are currently being developed for using the cellulosic materials (peels, skins, leaves, stalks, vines, pods, shells, and pits) from vegetable and fruit processing; the fat, collagen, blood, and bone from meat processing; and the whey generated during cheese manufacture. Enzymes are being used for treatment of food-processing waste streams; food-processing by-products serve as feedstocks for subsequent fermentation processes; and raw agricultural products function as renewable resources for the production of biofuels. Improvements in the utilization of food-processing waste streams will provide substantial cost savings and will dramatically decrease the contamination and pollution of the environment.

Tomorrow
As a science, food biotechnology is in its infancy. The current applications of biotechnology in agriculture and food merely hint at the tremendous potential which could be realized in the next 50 years. What does the future hold for food biotechnology? What can we expect to see by the year 2039, when the Institute of Food Technologists celebrates its centennial?

- Plant Biotechnology. In the next 50 years, our understanding of plant cells will rapidly expand. Sequencing of plant genomes will provide information on the structure and regulation of gene function at all levels—from the molecular and cellular to the whole-organism level. With this foundation, it will be possible to direct specific structural changes in components of plants through genetic engineering and predict what effect they will have on the functional properties of these components. Rather than shotgun approaches to plant improvement, predictable, precise, and controllable changes will be possible. Try to imagine:
  - Environmentally hardy food-producing plants that are naturally resistant to pests and diseases and capable of growing under extreme conditions of temperature, moisture, and salinity.
  - An array of fresh fruits and vegetables, with excellent flavor, appealing texture, and optimum nutritional content.

Table 3—Genetic Improvement of Food-Grade Microorganisms

<table>
<thead>
<tr>
<th>Type of fermentation</th>
<th>Nature of improvement</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy</td>
<td>Bacteriophage (virus) resistance</td>
<td>Elimination of economic losses due to destruction by viruses</td>
</tr>
<tr>
<td></td>
<td>Accelerated ripening</td>
<td>Decreased storage costs</td>
</tr>
<tr>
<td></td>
<td>Higher levels of beta-galactosidase</td>
<td>Increased digestibility for lactose-intolerant individuals</td>
</tr>
<tr>
<td>Meat</td>
<td>Production of bacteriocin (natural preservative)</td>
<td>Inhibition of pathogenic or spoilage organisms</td>
</tr>
<tr>
<td></td>
<td>Addition of cholesterol-reducing enzymes</td>
<td>Reduction of an undesirable dietary component</td>
</tr>
<tr>
<td></td>
<td>Addition of fat-modifying enzymes</td>
<td>Alteration of the ratio of saturated to unsaturated fat</td>
</tr>
<tr>
<td>Beer</td>
<td>Alpha-amylase production</td>
<td>Production of &quot;lite&quot; or low-calorie beer</td>
</tr>
</tbody>
</table>

Table 4—Microbial Production of Food Ingredients. From Wasserman et al. (1988)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Function</th>
<th>Producing organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>Acidulant</td>
<td>Acetobacter pasteurianus</td>
</tr>
<tr>
<td>Diacetyl</td>
<td>Buttery flavor</td>
<td>Leuconostoc cremonis</td>
</tr>
<tr>
<td>Dextran</td>
<td>Thickeners</td>
<td>Leuconostoc mesenteroides</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>Flavor enhancer</td>
<td>Corynebacterium glutamicum</td>
</tr>
<tr>
<td>Leucine</td>
<td>Amino acid</td>
<td>Brevisbacterium lactofermentum</td>
</tr>
<tr>
<td>Methylbutanol</td>
<td>Malt flavor</td>
<td>Lactococcus lactis subsp.</td>
</tr>
<tr>
<td>Monascin</td>
<td>Pigment</td>
<td>maligenes</td>
</tr>
<tr>
<td>Nisin</td>
<td>Antimicrobial</td>
<td>Monascus purpureus</td>
</tr>
<tr>
<td>Monosodium glutamate</td>
<td>Flavor enhancer</td>
<td>Lactococcus lactis</td>
</tr>
<tr>
<td>L-phenylalanine</td>
<td>Aspartame</td>
<td>Corynebacterium glutamicum</td>
</tr>
<tr>
<td>Vitamin B 12</td>
<td>Vitamin</td>
<td>Bacillus polymyxa</td>
</tr>
<tr>
<td>Xanthan gum</td>
<td>Thickener</td>
<td>Propionibacterium</td>
</tr>
</tbody>
</table>

- Environmentally hardy food-producing plants that are naturally resistant to pests and diseases and capable of growing under extreme conditions of temperature, moisture, and salinity.
- An array of fresh fruits and vegetables, with excellent flavor, appealing texture, and optimum nutritional content.
that stay fresh for several weeks.

- Custom-designed plants with defined structural and functional properties for specific food-processing applications.

- Food-Grade Microorganisms. An understanding of the molecular structure and regulation of gene function will extend the uses of industrially important microorganisms. It will be possible to program microorganisms to stably maintain, transcribe, translate, process, and express an ever-expanding number of characterized genes from other microbial as well as mammalian and plant sources. Try to imagine:
  - Cultures that are programmed to express or shut off certain genes at specific times during fermentation in response to environmental triggers.
  - Strains engineered to serve as delivery systems for digestive enzymes for individuals with reduced digestive capacity.
  - Cultures capable of implanting and surviving in the human gastrointestinal tract for delivery of antigens to stimulate the immune response or protect the gut from invasion by pathogenic organisms.
  - Microbially derived, high-value, "natural" food ingredients with unique functional properties.

- Processing Aids. Protein and enzyme engineering will become a standard tool for custom designing enzymes that function optimally under the temperature, pH, and moisture conditions used to process foods.

- Analytical Tools. Sophisticated, sensitive, reproducible, and rapid analytical methods will replace conventional techniques for identifying and quantifying pathogenic organisms, microbial toxins, chemical residues (pesticides, herbicides, heavy metals), and biological contaminants (hormones, enzymes). Try to imagine:
  - "Dip-stick" techniques that provide results in minutes rather than hours or days.
  - Biosensors that accurately measure the physiological state of plants; temperature-abuse indicators for refrigerated foods; and shelf-life monitors built into food packages.
  - On-line sensors that monitor fermentation processes, or determine the concentration of nutrients throughout processing to verify levels declared on labels.

- Waste Management. Creative handling of food-processing waste streams to produce value-added products will become a major area of interest and income to the food industry. Try to imagine:
  - Utilization of waste streams as a feedstock for production of biofuel to power processing plants.
  - Conversion of food-processing by-products into specialty chemicals for use by other industrial sectors.
  - Production of high-value pharmaceutical products from waste streams, such as whey, which currently cost the industry millions of dollars in disposal costs.

- The Diet–Health Interface. As we understand more about the role of diet in health and chronic disease, biotechnology could be used to custom design the food supply to meet the nutritional needs of specific target populations. One could imagine that with an increased understanding of animal metabolism it would be possible to engineer meat with reduced saturated fat, eggs with decreased levels of cholesterol, and milk with improved calcium bioavailability. As we unravel the mysteries of plant cell structure and function, it will be possible to engineer cereal grains with increased levels of specific components that mitigate or even prevent disease, such as soluble or insoluble fiber, omega-3-fatty acids, beta-carotene, or selenium. Ultimately, it will be possible to design an individualized diet to meet his or her needs.

### Future Challenges

A number of challenges facing the food industry must be overcome before the potential of biotechnology can be realized. Prior to their use in foods, the safety of the products of biotechnology will need to be verified. In addition, products will need to be approved by the various federal agencies that regulate the food supply, including FDA, the U.S. Dept. of Agriculture, and the Environmental Protection Agency. It is critical that the guidelines currently under development be consistent among agencies and that the extent of regulation be based on scientific fact rather than perceived risk. Without clear guidelines for the regulation of biotechnology products, the food industry will be reluctant to embrace biotechnology.

It is critical that... regulation be based on scientific fact rather than perceived risk. Without clear guidelines for the regulation of biotechnology products, the food industry will be reluctant to embrace biotechnology.
Food Biotechnology (continued)

technology if it is to survive and flourish in the agriculture and food sectors. If we have learned one lesson from the food irradiation issue, it is that consumer perceptions can have a dramatic impact on the implementation and utilization of a technology. We cannot ignore or trivialize the concerns of the public relative to food biotechnology. It is critical that the public be made aware of what biotechno-
ology is and how it could be used to solve some of the major problems in the world.

It is critical that the public be made aware of what biotechnology is and how it could be used to solve some of the major problems in the world: enabling agriculture and food processing to keep pace with population growth, controlling pollution of the environment and contamination of the water supply, and ensuring the health of the nation. The food processing industry, particularly the marketing sector, is acutely aware of consumer perception. If sales would be compromised by the use of biotechnology-derived foods, they would not be used by the industry.

The United States food processing industry, in general, has approached biotechnology cautiously. To pursue biotechnology-related research in corporate research facilities requires a major capital investment and long-term commitment. Unfortunately, trained molecular biologists with an appreciation for food technology are rare, and few universities have programs for training individuals to step into food industry positions in food biotechnology.

Although promises and speculations about what biotechnology might accomplish have been well publicized, the real impact on new food product development has not, at this time, been sufficiently demonstrated to encourage major research and development commitments by the management of most food companies. However, to meet consumer demands and keep pace in an increasingly competitive global marketplace, the U.S. food processing industry will need to enlist every available resource, including biotechnology. Industry must keep a finger on the pulse of biotechnology—monitor the biotechnology breakthroughs occurring in other scientific disciplines and be ready to apply these advances to food processing. The future will demand creative application of the tools of biotechnology to assure a safe, wholesome, nutritious, and affordable food supply for the generations to come.

The future will demand creative application of the tools of biotechnology to assure a safe, wholesome, nutritious, and affordable food supply for the generations to come.

References


—Edited by Neil H. Mermelstein, Senior Associate Editor
A Half Century of 
Food Microbiology

E.M. Foster

The history of any science is both tedious to write and often boring to read. So much depends on the skill, the inventiveness, the dedication, and even the biases of the historian. I do not present this brief story as a complete and detailed treatment of all that happened in a half century of food microbiology. Rather, it reflects some of my personal memories after 50 years of involvement in the subject. There will be serious omissions, oversights, and perhaps even errors. For these I apologize in advance. What I shall try to do in the space available is (1) describe the state of our knowledge of food microbiology when the Institute of Food Technologists was founded 50 years ago; (2) highlight some of the key advances and trends that occurred during the past half century (Table 1); and (3) mention some of the developments that we may expect to see in the years ahead.

What We Knew 50 Years Ago

Food microbiology began like all other applied sciences—to provide solutions to practical problems. S.C. Prescott of Massachusetts Institute of Technology responded to the needs of the infant canning industry. H.L. Russell of the Wisconsin Agricultural Experiment Station helped get the fledgling dairy industry on a solid base. He did some of the first work on sanitation of dairy equipment, and he showed the advantages of ripening cheese at low temperature. Russell also did some of the first work on thermal resistance of bacteria important to the canning industry.

These and a few other academic pioneers stimulated a very productive new generation of microbiologists whose interests centered on foods. Prominent among them, to name only a few, were L.A. Rogers of the U.S. Dept. of Agriculture's Dairy Division, E.G. Hastings and W.C. Frazier of the University of Wisconsin, J.M. Sherman of Cornell University, B.W. Hammer of Iowa State University, Harold Macy of the University of Minnesota, F.W. Tanner of the University of Illinois, and Carl Pedersen of the New York Agricultural Experiment Station. For many reasons, the greatest emphasis was on milk and milk products.

In 1939, microbiologists were mainly concerned with food preservation and spoilage. We knew the basic principles of the 3K system of food preservation: (1) Keep them out. This meant sanitation. (2) Kill them if you can. Heat was the only lethal agent that could be applied to food. The severity of heating, and therefore its bactericidal effectiveness, varied widely among foods and processes. (3) Keep the rest from growing. Various inhibitory means were available, all based on inhibiting enzyme reactions and thereby delaying growth. These included low temperature (refrigeration, freezing), low available water (drying, salting), low pH (acidification, fermentation), or inhibitory chemicals (preservatives). Then, as now, very few antimicrobial chemicals were permitted in foods. Application of these principles to specific industries was already well advanced in 1939.

- Canned Foods. After several disastrous outbreaks of botulism in the early 1920s, the canning industry was obliged to develop and adopt safe procedures that would effectively protect consumers against this dread disease. Accordingly, the National Canners Association (NCA; now the National Food Processors Association) undertook to measure the thermal resistance of botulinum spores in various canned foodstuffs. They also determined the heat penetration rates in different sizes and types of containers filled with various kinds of food. With this information, the canners' experts developed systems for determining a safe thermal process for any type of food in any type and size of container. The heat processes thus developed were extremely conservative, since their basic premise was to provide a heat treatment that would destroy 12 billion botulinum spores (the so-called 12D process.)

Thus, the canning industry was on solid microbiological grounds by 1939. With technical assistance available from NCA and the can manufacturers' technical staffs, operating canneries had very little trouble with botulinum spoilage. In fact, since 1925 the United States canning industry has produced more than a trillion containers of canned foods with only five or six known incidents of botulism. Many of these incidents involved faulty containers, not underprocessing.

For the first time in half a century, there seems to be widespread recognition that foodborne diseases are important to the public and need attention.

- Milk and Milk Products. Much like the canners, the dairy industry was driven to microbiological control by disease. From its beginning in the 19th century, the dairy industry was plagued by outbreaks of such milkborne diseases as typhoid fever, diphtheria, septic sore throat, brucellosis, tuberculosis, and others. Finally, the public health authorities established requirements covering animal health, sanitation, pasteurization, and refrigeration, all reinforced by bacterial specifications (standards). Thus, the dairy industry encountered mandatory microbiological controls long before the rest of the food industry, and by 1939 pasteurized milk was one of our safest foods. We had virtually eliminated bovine brucellosis and tuberculosis; we
had a highly developed system for cleaning and sanitizing milk-handling equipment; pasteurization was widely adopted for fluid milk products; and refrigeration throughout the distribution system assured adequate freshness control.

We also knew a great deal about starter cultures and fermented dairy products in 1939. Many factories cultured cream before churning it into butter. Cultured buttermilk made from skim milk by a combination starter of Streptococcus lactis and Leuconostoc species was an established product of commerce. Most cheese makers used known cultures rather than follow the "back slop" method of inoculating cheese milk with some of yesterday's whey. We knew which organisms to use in making each variety of cheese. By that time, we also knew about bacteriophages and their effect on acid development, but modern methods of phage control came later.

- Meat, Poultry, and Seafood. The meat industry was well developed in 1939. As today, the vast majority of meat products were preserved by refrigeration, which allowed only a relatively short keeping time. We knew the kinds and sources of organisms on meat and were well acquainted with the spoilages they caused, but we could do little to extend shelf life. Staphylococcal food poisoning was a well-recognized problem with cured hams. Fermented sausages were popular articles of commerce, but the production methods were largely empirical. Most manufacturers used the back slop method of inoculation with its inherent control difficulties.

The poultry industry in 1939 was nothing like it is today. Most chickens were raised on farms and sold locally. The turkey market was highly seasonal, the vast majority of birds being sold at Thanksgiving and Christmas. Bacterial spoilage was an important factor with both.

Microbial spoilage was the primary concern in connection with refrigerated storage of eggs in the shell. Heavy bacterial contamination was a recognized problem with frozen and dried eggs, but there was little concern about foodborne disease from egg products.

Fresh seafoods were available only near the coasts because of their high degree of perishability.

- Fruits and Vegetables. Only those fruits and vegetables that are most resistant to spoilage (e.g., apples, citrus fruits, cabbage, rutabagas, etc.) could be stored and distributed in the fresh state as we do today. Modified-atmosphere storage was practiced with apples and a few other fruits for long holding periods or transoceanic shipment. Berries, tomatoes, lettuce, and other perishable fruits and vegetables were available only in season. We knew the causes of microbial spoilage, but our refrigeration facilities, both fixed and mobile, were not good enough to assure the prolonged shelf life that we enjoy today.

The microbiology of fermented fruits and vegetables was well understood in 1939. We were thoroughly familiar with the organisms involved in both production and spoilage of sauerkraut, cucumber pickles, and fermented olives.

- Foodborne Disease. Surprisingly, we heard very little about foodborne disease 50 years ago. The chief academic interest in this subject was found in the Bacteriology Dept.
at the University of Chicago. First E.O. Jordan in 1917
and later Gail M. Dack in 1943 published books under
the same title, Food Poisoning. Both dealt with various
human and animal pathogens that can be transmitted by
food. However, the only conventional food-poisoning
bacteria mentioned in either book were Clostridium botuli-
num, Staphylococcus aureus, and Salmonella spp.

We knew a great deal about botulism in 1939 because of
the work done to save the canning industry. As far as we
knew at that time, botulism was primarily a problem of
home canners. Now we realize it is much more widespread
than that.

Staphylococcal food poisoning was a frequent problem
with cream-filled baked goods, cured ham, various salads,
roast fowl, and, occasionally, certain types of cheese.
Outbreaks of this disease almost invariably indicated recon-
tamination from human sources plus mishandling of the
food in a way that allowed S. aureus to grow and produce
its enterotoxin.

Fifty years ago, we knew that salmonellosis was com-
monly transmitted by animal products, but we believed
that those animals were sick. Now we know that apparently
they were with some vague “ptomaine” that might make
people who had just survived the great depression of the
war. We had to have better rations to feed our troops, who
were more concerned with getting enough to eat than
even poorer in 1939 than they are today, but there is no
evidence to indicate that foods were more or less safe then
than they are now. The apparent lack of concern about
foodborne disease 50 years ago may simply indicate that
people who had just survived the great depression of the
1930s were more concerned with getting enough to eat than
they were with some vague “ptomaine” that might make
them sick for a few hours.

What We Have Learned

We have learned a number of lessons in the decades
since 1939:

• 1939–59. World War II began 50 years ago, but the
U.S. did not enter the conflict until 1941. Food technolo-
gists became heavily involved after the U.S. entered the
war. We had to have better ration to feed our troops, who
were fighting all over the world. The food industry was
mobilized to develop products that would feed and nourish
our fighting men in every kind of environment from the
frozen arctic to the humid tropics. We also provided huge
amounts of food for our allies in the European theater.

It was just this circumstance that led to the discovery of a
previously unrecognized health hazard. People in Great
Britain began to suffer outbreaks of salmonellosis caused by
serotypes that had not previously been observed in the
British Isles. In time, it was learned that spray-dried eggs
from the U.S. and Canada were the vehicle for transmit-
ting the new Salmonella serotypes to the British people.

Although this was one of the first, it was by no means
the last instance of salmonellosis involving American
processed foods. Dried or frozen eggs were the vehicle in
several subsequent outbreaks of disease among U.S. civil-
ians. Later, in 1955, dried yeast and dehydrated coconut
were identified as vehicles of salmonellosis.

Meanwhile, there was little change in the overall thrust
and activity of food microbiologists. Even though numer-
ous developments of food science were formed in our
universities after the war, the primary emphasis of food
microbiologists continued to be directed toward preserva-
tion and spoilage. The heavy emphasis on dairy products
was balanced somewhat by research on meats and other
foods; yet there was little interest in foodborne disease.

One notable event of the decade was the discovery of
aflatoxins in 1959, when thousands of turkey poults died in
Great Britain after eating moldy peanut meal. Theretofore,
we had regarded molds on food simply as pesky spoilage
agents with no health significance. The aflatoxins were the
first of dozens of poisonous fungal metabolites to be
discovered in food systems. The full significance of these
materials is still not understood.

• 1960–69. The new decade started with a special
challenge for food microbiologists and the food industry.
In 1960, two people in Minneapolis died of Type E
botulism after eating smoked fish from Lake Superior. In
1962, two other incidents of Type E botulism with at least
seven deaths were attributed to fish caught in the Great
Lakes and smoked in Michigan. Two of the three incidents
involved vacuum-packaged commercial products that were
shipped across state lines. This was the first time that Type
E botulism had been attributed to freshwater animals.
Ocean fish were known sometimes to harbor C. botulinum
Type E, but these were the first outbreaks involving
freshwater fish.

Surveys of the Great Lakes revealed C. botulinum Type
E as a frequent contaminant of fish from those waters.
Therefore, temperature abuse after processing was the only
requirement for toxin to develop. In the outbreaks cited,
the fish were transported in warm weather without ade-
quate refrigeration. These incidents provide a classic exam-
ple of the danger one faces when relying solely on
refrigeration to protect low-acid cooked foods from micro-
bial hazard.

Meanwhile, processed foods continued to serve as vehi-
cles of salmonellosis from time to time. In 1961, an
outbreak was attributed to instant infant cereal manufac-
tured in Sweden. In 1963, cottonseed protein was responsi-
ble for a small outbreak; and in 1966, there were four
identifiable incidents. The vehicles were smoked whitefish,
headcheese, carmine red dye (food color), and instant
nonfat dry milk.

Government authorities, meanwhile, recognized the
repeatedly demonstrated hazard of salmonellosis from pro-
cessed eggs and in 1965 required that all liquid eggs to be
frozen or dried must be pasteurized. This is probably the
single most important action that our government has taken
to protect the American people against foodborne salmo-
nellosis.

Perhaps the most significant event of the 1960s from a
microbiological point of view was the appointment of Dr.
James Goddard as Commissioner of the Food and Drug
Administration in 1966. Goddard had been Director of
the Centers for Disease Control and was well aware of the
concerns then held about Salmonella in food. His arrival at
FDA shortly preceded a nationwide outbreak of Salmonel-
lar New Brunswick infection involving some 28 cases, many
of them infants, where the vehicle was instant nonfat dry
milk. Under Goddard’s guidance, FDA undertook an
intensive surveillance program, testing virtually every dry
food and food ingredient that had ever been associated

We have discovered several new
foodborne disease agents during
the past 10 years. . . . The only
thing new about them is the
realization that they can be
transmitted to man by food.
with Salmonella—yeast, eggs, milk, gelatin, cottonseed protein, spices, animal glandular extracts, and on and on. They tested thoroughly, and they often found the organism.

Salmonella was, and still is, considered to be an adulterant, and any product found to contain the organism had to be removed from the market. This produced some very expensive product recalls and severe economic hardship on the affected industry, but it certainly got industry’s attention. For the first time, the U.S. food industry as a whole became aware of pathogenic and toxigenic organisms as problems it had to do something about. The industry had to find ways to protect its products from contamination. Whether this campaign did much to improve public health is debatable, but it certainly did a great deal to clean up a lot of food plants in the U.S. Needless to say, it also created a large number of jobs for microbiologists, in both the industry and the regulatory agencies.

Meanwhile, efforts to do something about Salmonella in meat and poultry, where the real health problems are believed to exist, were thwarted by a court decision that Salmonella in poultry (and, by inference, in other raw animal products) is an unavoidable defect. Thus, neither government nor industry has been impelled to contribute the necessary effort into developing ways to avoid contamination of raw animal products with Salmonella.

- 1970–79. The decade of the 1970s saw little increase in the public awareness of microbial hazards in food. Two or three small outbreaks of botulism from commercially canned foods were publicized briefly but soon forgotten.

**During the 1970s . . . the news media and the consumer activists seemed determined to convince the public that the American food supply is unsafe, unwholesome, and dangerous.**

The lessons of these events were not lost, however, on the regulatory agencies, nor did they go unnoticed by the companies involved, all of whom suffered grievous economic loss. The net result was a new regulatory structure covering the canning industry. FDA now has vastly broader powers to regulate virtually everything the canning industry does.

Meanwhile, the food processing industry learned to live with FDA’s requirements for Salmonella control. Manufacturers put pressure on their suppliers, while FDA’s fervor to look for Salmonella in processed foods understandably waned. Neither USDA nor the animal industries did anything of significance to solve the problem of Salmonella in raw animal products.

Throughout all this, foodborne disease continued to be common, but nobody knew how common. The incidence figures for botulism, staphylococcal food poisoning, salmonellosis, and the other well-known foodborne diseases did not change much from year to year. Occasionally, we heard of a new and unfamiliar agent, such as Escherichia coli O27:H20, which caused a nationwide outbreak of gastroenteritis in 1971. The vehicle was Brie cheese imported from France. Disease outbreaks caused by Yersinia enterocolitica and Campylobacter jejuni were heard of near the end of the decade, but received little attention except from specialists in foodborne disease control.

**Table 1—Highlights in Food Microbiology**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early 1920s</td>
<td>12-D process for canned foods developed</td>
</tr>
<tr>
<td>Mid-1920s</td>
<td>Universal pasteurization adopted and safe milk assured</td>
</tr>
<tr>
<td>Before 1939</td>
<td>Widespread use of pure culture starters for fermented foods</td>
</tr>
<tr>
<td>1943–45</td>
<td>Salmonella recognized as a problem in dried eggs</td>
</tr>
<tr>
<td>1959</td>
<td>Aflatoxins discovered; many other mycotoxins follow</td>
</tr>
<tr>
<td>Early 1960s</td>
<td>Type E botulism hazard from Great Lakes smoked fish discovered</td>
</tr>
<tr>
<td>1965</td>
<td>Mandatory pasteurization of liquid eggs adopted</td>
</tr>
<tr>
<td>Late 1960s</td>
<td>Salmonella contamination found in many dried foods</td>
</tr>
<tr>
<td>Early 1970s</td>
<td>Low-acid acidified canned food regulations adopted by FDA</td>
</tr>
<tr>
<td>1985</td>
<td>World’s largest outbreak of salmonellosis attributed to pasteurized milk in Chicago</td>
</tr>
</tbody>
</table>

Actually, most of the public’s attention during the 1970s was devoted to potentially toxic chemical constituents in food. Beginning with President Nixon’s order in 1969 to reexamine the safety of substances on the Generally Recognized as Safe (GRAS) list, the news media and the consumer activists seemed determined to convince the public that the American food supply is unsafe, unwholesome, and dangerous. Besides scores of unsafe additives, toxic pesticide residues, and dangerous chemical contaminants in our foods, new questions were raised about the danger of consuming too much salt, cholesterol, and saturated fats. At the same time, we were urged to eat more fiber. People in government, and many outside of government, did their best to reshape the American diet to fit a common mold for everybody, even though many of the recommendations were, and still are, hotly debated by the nation’s leading nutrition scientists.

- 1980–89. Matters continued about as usual for the first half of the 1980s. C. jejuni emerged as the leading cause of gastroenteritis. According to a survey of some of the nation’s major hospitals, Campylobacter causes more disease than Salmonella and Shigella combined. Y. enterocolitica was identified in several sizable outbreaks of gastroenteritis, most of them from dairy products. One in particular was worrisome. It involved an estimated 1,200 cases attributed to consumption of pasteurized milk processed in a large modern dairy. The milk must have been recontaminated after pasteurization, but no one has yet discovered the source of the organism. E. coli O157:H7 first appeared in 1982 among patrons of a fast-food restaurant chain. It has subsequently caused serious and sizable disease outbreaks in nursing homes, retirement homes, schools, and other institutions. This organism
produces a very serious type of colohemorrhagic colitis, or "bloody diarrhea," sometimes followed by hemolytic uremic syndrome, a frequent cause of kidney failure, and sometimes death, in young children. Epidemiologic evidence usually points to beef or chicken as the source. One large outbreak involving Canadian kindergarten children was attributed to consumption of unpasteurized milk.

Aeromonas hydrophila also was recognized in the early part of the decade as a possible cause of foodborne disease. There are still doubts about its significance, but the evidence is highly suggestive that it can be transmitted by food and cause disease. This organism is common in water and raw animal products.

Finally, the marine vibrios deserve mention. We have known for many years that Vibrio cholerae, the cause of Asiatic cholera, can be transmitted to man by contaminated food and water. This organism has been found in seafood taken from the Gulf of Mexico. Also, we have known for a long time that V. parahaemolyticus, the leading cause of foodborne disease in Japan, can be found in seafood from our coastal waters. Only recently, however, did we learn that V. vulnificus also occurs in these same waters. This highly invasive organism is one of the most dangerous bacteria known. We can contract it through skin lesions or via the alimentary tract. The organism is commonly associated with oysters, and infection can be acquired by eating raw shellfish.

It is clear from the foregoing paragraphs that we have discovered several new foodborne disease agents during the

During the past 20 years . . . we have become increasingly concerned about the safety of foods. . . . In the minds of many, the term food microbiology has become synonymous with the microbiology of foodborne disease.

past 10 years. Many of them are well-known pathogens of domestic animals. The only thing new about them is the realization that they can be transmitted to man by food. However, this decade will long be remembered for one year, 1985. Just as 1966 was a banner year for food microbiologists, 1985 has served to impress everyone—regulators, congressmen, news media, industry, consumer activists, and even the general public—that foodborne disease is an important consideration regarding the safety of foods. This concern includes microbial safety, which has become especially acute since 1985. In the minds of many, the term food microbiology has become synonymous with the microbiology of foodborne disease.

What Lies Ahead

Food microbiologists face a number of challenges in several areas in the future:

- Methods Development. Fifty years ago, our concerns for microbiological safety were concentrated on drinking water, fluid milk, and canned foods. All of these had a history of disease transmission, all had been made safe, and all were monitored by some kind of microbiological control mechanism. For water and milk, we used plate counts and coliform tests to indicate possible hazards. For canned foods, we relied on process controls supplemented with thermophile counts in sensitive ingredients. We did not test directly for pathogenic organisms.

Our experience of the past 20 years has shown that these are not enough for most foods; we must look for the pathogen itself if we are to be sure a food is safe.

Food microbiologists . . . face an urgent challenge—how can we detect very low numbers of pathogenic microorganisms in a food product quickly, cheaply, and reliably?
A Half Century of Food Microbiology (continued)

Unfortunately, we do not yet have methods that are fast enough and sensitive enough to detect pathogens on a routine basis in a quality control laboratory. Even an ordinary Salmonella test, after 20 years of effort, still takes 5-7 days for a definitive answer.

Thus, food microbiologists and others involved in methods development face an urgent challenge—how can we detect very low numbers of pathogenic microorganisms in a food product quickly, cheaply, and reliably? A side issue to this question is the matter of infective dose. What is a safe level of pathogenic organisms in food? This question has always been a concern with Salmonella, and it has arisen more recently in testing for Listeria monocytogenes. It will continue to plague us until some kind of decision is reached.

- Psychrotrophic Pathogens. For many years, we accepted the general conviction that pathogenic microorganisms are unable to grow at refrigeration temperatures. This view was weakened only slightly a quarter of a century ago when we learned that Clostridium botulinum Type E can grow and produce its deadly toxin in refrigerated food. Events of the past 10 years, however, have shown that several pathogenic bacteria can, indeed, multiply in properly refrigerated foods and food plant environments. Organisms that can do this include L. monocytogenes, Y. enterocolitica, A. hydrophilia, and nonproteolytic strains of C. botulinum Types B and F.

This finding has enormous significance for cooked, low-acid products that are preserved for extended periods of time under refrigeration. Where other circumstances allow growth and spoilage, refrigeration may simply provide conditions for selective enrichment of the psychrotrophic pathogens.

- Animal Pathogens. We have known for a long time that salmonellae are common in raw animal products, i.e., poultry, meat, milk, and eggs. Now we know that Listeria and Aeromonas are even more common, and Campylobacter is especially numerous on raw poultry.

In the past, we have relied on cooking and proper handling to protect us from these dangerous organisms, yet mistakes occur and illness often results. From a public health standpoint, it would be far better if the raw animal products were free of pathogens when they enter the marketplace. Thus, eliminating pathogens, or even reducing their number on raw products, offers a challenge to the animal industries of the future.

- Biotechnological Developments. Aside from its role in methods development, which now looks very bright, biotechnology is likely to produce fundamental changes in food fermentations. Improved starter cultures and better organisms for enzyme production are only two of the areas that offer great opportunities to the food microbiologist. Equally attractive is the use of microorganisms to produce desirable food flavors, either directly in the food or for addition to food.

A Bright Outlook

Food microbiology has gained great significance in the food industry during the past 50 years, largely because of increased recognition of foodborne disease problems. Preventing disease obviously will be an essential part of future quality control programs. The outlook for food microbiologists in both industry and regulatory agencies is brighter today than it has ever been.
Nutrition: Past, Present, and Future

John W. Erdman Jr.

This review will focus on decade-to-decade advances in the nutrition field in the past 50 years, especially as they affect food science in the United States. The present status of nutritional sciences and fertile areas for future nutrition research and policy will also be emphasized.

The Discovery Era: 1700s–1939

We often trace the field of nutrition back to James Lind, the British naval surgeon who carried out what was probably the first controlled human dietary study. In 1747, Lind demonstrated that citrus fruits relieved the symptoms of scurvy in English sailors. However, it was almost 50 years before his results were practically applied when the British Navy officially introduced lemon juice as a prophylactic against scurvy (Todhunter, 1976).

Many other giants, such as Lavoisier, Liebig, Prout, Dumas, and Atwater made major contributions before and into the early part of the 20th century. (For more information on the historical development of nutrition, see McCollum, 1957; Lusk, 1933; McCoy, 1973; Todhunter, 1976; 1984; Darby, 1985; Harper, 1988; and Hill, 1978. In addition, an excellent collection of materials can be found in the History of Nutrition Archives and Collection, Vanderbilt University Medical Center Library, Nashville, Tenn.)

In spite of these contributions, the techniques in analytical chemistry of organic molecules in the early 1900s were so weak that it remained to be proven that animals needed more than palatable purified diets containing protein, energy sources, water, and a few minerals to survive (see, e.g., Harper, 1988).

From about 1906 to 1916, two major research groups, that of Osborne and Mendel at Yale University and that of McCollum and Davis at the University of Wisconsin, began the study of vitamins by showing that previously unknown organic factors were necessary for adequate growth and viability of animals. They extracted “fat-soluble A” from butter and “water-soluble B” from natural products and demonstrated that both were required growth factors. Casimir Funk coined the term “Vitamine” in 1912 to classify those dietary organic substances that were necessary to prevent dietary deficiency diseases. The researchers from Yale and Wisconsin catalyzed the development of the nutrition field, as researchers from many of the basic and agricultural science fields worked feverishly to identify not only the organic but also the inorganic growth promoters.

Table 1 is a chronology of selected advances in nutrition in the 20th century. I have termed the period from the 1700s to 1939–40 “the discovery era” to reflect the intense interest of nutritionists during this period in isolating and identifying essential growth factors in foods.

The nutrition literature began to flourish near the end of the discovery era, and nutrition began to emerge as a distinct discipline. In 1939, the British publication, Nutrition Abstracts and Reviews, was but 8 years old, Journal of Nutrition was 11 years old, and Food Research (later renamed Journal of Food Science) was 3 years old. A review of research articles from these and other journals a half century ago reveals a great deal of high-quality work, much of which is still valid today. Clearly, researchers of that time were severely handicapped by the lack of many of the advanced analytical tools we enjoy today. Nevertheless, the pioneers in the field moved forward steadily . . . .

A half century ago . . .

The Transition Period: 1939–40

Nutrition as a scientific discipline was barely past the toddling stage when the Institute of Food Technologists was formed 50 years ago. As noted by Sir Walter Fletcher (1932), nutrition “is cross-bred in its origin, being related to practically every branch of biological science and is only now becoming recognized as a separate branch of applied science.” The nutrition researchers a half decade ago were quite capable, their work was thoughtfully and carefully carried out, and their publications often caused a stir among fellow scientists. Nutrition was simply a poorly developed science lacking adequate methods of analysis.

1939, the year that IFT was established, can be considered a major transition point for nutritional science. Most essential growth factors in foods had by then been discovered, and the research emphasis was shifting toward unraveling the exact function of these nutrients in human metabolism. E.V. McCollum, who was president of the American Institute of Nutrition in 1939, provided a snapshot of the nutrition field at this point (McCollum, 1957):

It seems logical to close this history of ideas with the year 1940. Essentially that year marks the achievement of the primary objectives set by pioneers in their field of study. They sought to discover what in terms of chemical substances constituted an adequate diet for...
man and domestic animals, and that purpose was realized. He also noted that by 1940 scientists realized that: an adequate diet must provide, in appropriate amounts, forty or more specific chemical substances identified as amino acids, vitamins, fatty acids, carbohydrate and inorganic elements. With the exception of folic acid and vitamin $B_{12}$, by 1940 these have been identified, isolated and characterized chemically.

Krehl (1978), reflecting on McCollum's statements, suggested that the milestone year of 1940 represented "the end of the beginning" of the science of nutrition.

Although the precise end date of the discovery era is somewhat arbitrary, discovery of which "chemical substances constituted an adequate diet" was indeed realized about this time. This was also an appropriate date for IFT to be established.

1939, the year that IFT was established, can be considered a major transition point for nutritional science.

The Biochemical Function Era: 1940–89

A primary emphasis of nutrition researchers over the past 50 years has centered on determining the biochemical functions and mechanisms of action of essential nutrients. In this "biochemical function era," numerous advances were made as nutritionists progressed beyond the "feed them and weigh them" studies to utilize the latest biochemical...
ical techniques. Although much progress has been made in the past half century, the precise mode of action of some of the fat-soluble vitamins and trace elements still eludes us.

Another goal during this era has been to more accurately determine the nutritional requirements for farm animals, pets, and humans. For domesticated animals the emphasis has been to optimize growth, while for humans the primary goal has been to establish levels of intake which would prevent nutritional deficiency diseases.

- Impact of World War II. The outbreak of World War II in Europe helped to usher in the new biochemical function era. It resulted in a request from the U.S. Dept. of Defense to the National Academy of Sciences to provide assistance with nutrition planning related to national defense. This led to the permanent establishment of the Food and Nutrition Board in 1941 and the first edition of the Recommended Dietary Allowances two years later. The first of nine editions so far was designed to serve "as a guide for planning and procuring food supplies for national defense" (NAS/NRC, 1943). Clearly, the RDAs have found great use by nutrition professionals and federal nutrition programs. In addition, the regular publication of RDAs has fostered a great deal of research on defining human nutritional requirements.

World War II also stimulated an increased emphasis on nutrition research. According to Krehl (1978):

During the World War II years, extraordinary efforts were made in a number of laboratories to obtain

<table>
<thead>
<tr>
<th>1900–39: The End of the Discovery Era</th>
<th>The End of the Discovery Era (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1902</td>
<td>Pellagra reported in the U.S.</td>
</tr>
<tr>
<td>1903</td>
<td>Bomb calorimeter for foods and physiological materials designed by Atwater</td>
</tr>
<tr>
<td>1904</td>
<td>Respiration calorimeter for human studies developed by Atwater</td>
</tr>
<tr>
<td>1906</td>
<td>Tryptophan determined to be an essential amino acid</td>
</tr>
<tr>
<td>1906–28</td>
<td>Classic studies on the nutritive value of proteins performed by Osborne and Mendel</td>
</tr>
<tr>
<td>1912</td>
<td>The term “Vitamine” coined by Funk</td>
</tr>
<tr>
<td>1913</td>
<td>Goldberger given task to cure pellagra in the U.S.</td>
</tr>
<tr>
<td>1913–16</td>
<td>Fat-soluble and water-soluble growth factors discovered by McCollum and Davis and Osborne and Mendel</td>
</tr>
<tr>
<td>1917</td>
<td>Iodine treatment shown to be effective against goiter in children</td>
</tr>
<tr>
<td>1917</td>
<td>American Dietetic Association founded</td>
</tr>
<tr>
<td>1918</td>
<td>Phosphorus determined to be essential for rats</td>
</tr>
<tr>
<td>1921–24</td>
<td>Blindness in children shown to be the result of lack of vitamin A</td>
</tr>
<tr>
<td>1921</td>
<td>Rickets treated with sunlight exposure</td>
</tr>
<tr>
<td>1922–24</td>
<td>Vitamin E discovered by Evans and Bishop</td>
</tr>
<tr>
<td>1922</td>
<td>Vitamin D found in cod liver oil</td>
</tr>
<tr>
<td>1922</td>
<td>Methionine discovered</td>
</tr>
<tr>
<td>1924</td>
<td>Iodization of table salt begun in Michigan</td>
</tr>
<tr>
<td>1926</td>
<td>Liver used (in large amounts) in the treatment of pernicious anemia</td>
</tr>
<tr>
<td>1928</td>
<td>Goldberg identified pellagra-preventing factor in yeast</td>
</tr>
<tr>
<td>1929</td>
<td>Copper found to be essential for rats</td>
</tr>
<tr>
<td>1930</td>
<td>Conversion of carotene to vitamin A in vivo shown by Moore</td>
</tr>
<tr>
<td>1931</td>
<td>Magnesium and manganese shown to be essential for the rat</td>
</tr>
<tr>
<td>1932</td>
<td>Crystalline vitamins C and D prepared</td>
</tr>
<tr>
<td>1933</td>
<td>Kwashiorkor identified as a nutritional disease by Williams</td>
</tr>
<tr>
<td>1934</td>
<td>First U.S. dietary standards published by Stiebling of U.S. Dept. of Agriculture</td>
</tr>
<tr>
<td>1935</td>
<td>American Institute of Nutrition founded</td>
</tr>
<tr>
<td>1936</td>
<td>Vitamin K discovered by Dam</td>
</tr>
<tr>
<td>1937</td>
<td>Zinc found to be essential for the rat</td>
</tr>
<tr>
<td>1938</td>
<td>Threonine discovered as an essential amino acid by Rose</td>
</tr>
<tr>
<td>1939</td>
<td>First Household Food Consumption Survey conducted by USDA (repeated 1942, 1948, 1955, and 1965)</td>
</tr>
<tr>
<td>1940</td>
<td>Nicotinic acid identified as anti-black tongue (in dogs) factor by Elvehjem</td>
</tr>
<tr>
<td>1940–89: The Biochemical Function Era</td>
<td>Institute of Food Technologists founded</td>
</tr>
<tr>
<td>1941</td>
<td>FDA promulgates standards for enrichment of flour and bread with B-complex vitamins and iron</td>
</tr>
<tr>
<td>1942</td>
<td>Nutrition Foundation chartered</td>
</tr>
<tr>
<td>1943</td>
<td>First edition of the RDAs published by the National Academy of Sciences</td>
</tr>
</tbody>
</table>
information on the effects of cooking and processing losses on the nutritive value of foods and the changing nutritional requirements under stress. Extensive studies were conducted on the nutritional quality of food rations that had been developed by the Armed Forces Quartermaster Corps. The shocking physical status of draftees, showing evidence of present or past malnutrition, alerted the country to the importance of improving nutritional status through improvement of our food supplies.

- 1940s and '50s. The 1940s, in particular, marked the initial application of the results of basic nutrition research. With federal, private, and academic cooperation, technology for the enrichment of flour and bread with certain B-complex vitamins and iron was developed and implemented in many states as a public health measure to increase the intake of these nutrients. Following World War II, the fortification of foods flourished, as technological advancements made it possible to add affordable forms of nutrients which were stable in foods during processing and storage. Fortification, restoration, and enrichment of foods have made dramatic impacts on the nutritional status of Americans and people elsewhere throughout the world.

The impact of federal agencies, especially the Food and Drug Administration, during this period, must be highlighted. The establishment of the National School Lunch Program and other federal feeding programs, the develop-

<table>
<thead>
<tr>
<th>The Biochemical Function Era (continued)</th>
<th>The Biochemical Function Era (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945 Pteroylglutamic acid synthesized</td>
<td>1971 1,25-dehydroxycholecalciferol isolated as metabolically active form of vitamin D-3</td>
</tr>
<tr>
<td>Fluoridation of water supply begun in Grand Rapids, Mich.</td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12 identified, isolated from liver</td>
<td></td>
</tr>
<tr>
<td>Framingham Study initiated</td>
<td></td>
</tr>
<tr>
<td>Molybdenum found in the essential enzyme xanthine dehydrogenase</td>
<td></td>
</tr>
<tr>
<td>Vitamin B-6 shown to be essential for infants</td>
<td></td>
</tr>
<tr>
<td>Amino acid requirements in young men determined by Rose</td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12 structure determined</td>
<td></td>
</tr>
<tr>
<td>Zinc deficiency in man reported by Prasad</td>
<td></td>
</tr>
<tr>
<td>Selenium demonstrated to be essential for animals</td>
<td></td>
</tr>
<tr>
<td>Food Additives Amendment, Delaney clause, and GRAS lists established by FDA</td>
<td></td>
</tr>
<tr>
<td>1955 Vitamin B-12 structure determined</td>
<td>1977 U.S. Senate Select Committee on Nutrition and Human Needs issues two editions of Dietary Goals for the United States</td>
</tr>
<tr>
<td>Zinc deficiency in man reported by Prasad</td>
<td>1979 Selenium used in prevention of Keshan disease in China</td>
</tr>
<tr>
<td>Wald receives Nobel Prize for demonstrating the role of vitamin A in night blindness</td>
<td>Healthy People: The Surgeon General’s Report on Health Promotion and Disease Prevention published by HEW</td>
</tr>
<tr>
<td>1954–55 Amino acid requirements in young men determined by Rose</td>
<td>17 nutrition objectives to be achieved by 1990 published by HHS</td>
</tr>
<tr>
<td>1955 Vitamin B-12 structure determined</td>
<td>1982 Diet, Nutrition and Cancer published by NAS/NRC</td>
</tr>
<tr>
<td>1957 Selenium demonstrated to be essential for animals</td>
<td>1985 Brown and Goldstein receive Nobel Prize for work with lipoprotein receptors</td>
</tr>
<tr>
<td>1958 Food Additives Amendment, Delaney clause, and GRAS lists established by FDA</td>
<td>1988 The Surgeon General's Report on Nutrition and Health published by HHS</td>
</tr>
<tr>
<td>1963 Zinc deficiency in man reported by Prasad</td>
<td>1989 Diet and Health: Implications for Reducing Chronic Disease Risk published by NAS/NRC</td>
</tr>
</tbody>
</table>
Nutrition: Past, Present, and Future (continued)

With the completion of nutrition labeling and fortification guidelines, and the completion of several nationwide food consumption and health surveys, we have greatly advanced our ability to identify nutritional deficiencies in the U.S. population. These efforts have helped to correct nutritional problems and have stimulated additional research in human nutrition.

- 1960s and '70s. The 1960s and '70s were notable as a period of continued interest in malnutrition and as the time of the emergence of federal, professional, and consumer interest in the adverse effects of overnutrition. Evidence of hunger and malnutrition in the poverty groups in the U.S. was reported from the Preschool Nutrition Survey and the Ten-State Nutrition Survey carried out in the late 1960s. The White House Conference on Nutrition and Health convened by President Nixon in 1969 increased public awareness of undernourished Americans.

At the same time, there emerged concerns over the problem of nutrient excesses by many Americans, especially intake of excess calories and fat. Because of the rapid and persistent increase in deaths from heart disease and stroke in the 1950s and '60s, the American Heart Association initiated in 1957 (and again in 1965, 1968, 1978, and 1988) public education programs advancing the concept of the relationship of dietary risk factors to health. The Senate Select Committee on Nutrition and Health Needs published two editions of the Dietary Guidelines for the United States in 1977. The AHA and Senate Select Committee recommendations for all Americans to reduce the intake of animal fats, saturated fats, and cholesterol were highly controversial but have largely been echoed in dietary guidelines published by numerous federal and professional groups in subsequent years (for a review of published dietary guidelines, see HHS, 1988, and Cronin and Shaw, 1988).

The '60s and '70s can also be identified as a time of increased sophistication of equipment, methods, and approaches to research. Advances in chromatographic methods affect absorption and utilization of nutrients. The interaction of nutrients occupied a more central role among nutrition researchers as consumers increased their intake of fortified foods and nutrient supplements.

- 1980s. The two most striking impressions obtained from a review of the past decade of research are the overwhelming focus on diet and health and the research concentration on the effect of nutrients on genetic expression.

The avalanche of publications in the 1970s and '80s from ten different federal and professional organizations listing a series of dietary recommendations for promotion of optimal health (HHS, 1988; Cronin and Shaw, 1988) have increased public awareness of possible effects of diet on chronic disease. Along with this increased awareness have come increased public expectations of the power of good nutrition, many of which cannot now, and perhaps never will, be realized.

For example, it is clear today that the amounts of dietary fat, calories, and cholesterol play a role in the incidence of coronary heart disease in the U.S. population, and that the amount of dietary fiber affects some diseases of the colon. The specific details, however, such as what types of fatty acids and fiber cause these effects, are still under study. Other issues, such as the role of individual nutrients in the incidence of specific types of cancer, osteoporosis, mood change, athletic performance, hyperactivity, allergic response, immune function, hypertension, aging, etc., are also being studied. Unfortunately, health claims in many of these areas have often preceded appropriate scientific studies.

Nutrition has been considered a panacea for a variety of illnesses by far too many people. Although food and components of food have always been vulnerable to health claims, and indeed to fraud, expectations of the ability of nutrients to prevent or cure diseases have never been higher. To avoid providing incorrect or perhaps harmful information to consumers, the scientists, federal agencies, and professional groups involved must guard against the current trend of making policy decisions, holding news conferences, and making sweeping dietary recommendations before appropriate studies are completed.

Another notable feature of nutrition in the 1980s is the aggressive pursuit of an understanding of how nutrients affect specific intracellular events at the gene level. Nutrition researchers are utilizing a variety of techniques developed by molecular biologists to study metabolic regulation of genes. Many of the recent studies by nutritionists have focused on the role of a nutrient (usually a vitamin or a trace mineral) in (1) the modulation of enzyme activity; (2) the synthesis, turnover, or degradation of extracellular, intracellular, cell-surface, or nuclear-binding proteins; (3) the expression of specific messenger or other ribonucleic acids in cells and tissues; and (4) the regulation of metabolic sequences (see Rucker and Tinker, 1986, for a discussion of the role of nutrition in gene expression).

Other research in the past decade has focused on the role of nutrients in immune response, an area which has tremendous potential application to the control of infections, diseases, and allergic reactions. Other researchers are directing their efforts toward understanding the interrelationship of specific nutrients and hormones in metabolic control. The effects of various types of stress, both dietary and nondietary in origin, on nutrient requirements and...
Nutritional status are also under study. In addition, efforts to delineate the factors that affect the bioavailability of nutrients and the metabolic effects of nutrient-nutrient interactions have continued (see Bodwell and Erdman, 1988).

Another Crossroads
Fifty years ago, the nutrition field was at a crossroads. The discovery era was ending, as most essential nutrients had been identified, and the biochemical function era was beginning, as researchers began concentrating their efforts on the mode of action of nutrients. Today, we again find ourselves at a crossroads. Clearly, the biochemical function era is continuing, and there is still much to accomplish on many fronts. Yet we are simultaneously involved in another period which I call the "preventive nutrition era."

Over the past few years, diet and health issues seem to have taken on more importance than the more classical biochemical function studies. Publicity from various federal agencies, professional and consumer groups, and the mass media has centered upon preventing coronary heart disease, cancer, osteoporosis, hypertension, and other problems. The focus is now upon problems of chronically low intakes of a vitamin or mineral and the related nutrient deficiency diseases. The focus is now upon nutrient excesses (calories, fat, saturated fat, sodium, etc.); imbalances of dietary intake patterns (low- vs high-fiber foods, high- vs low-fat foods, balance of saturated, monounsaturated, polyunsaturated, \( \omega-3 \) and \( \omega-6 \) fatty acids, etc.); and the role of nutrients in the prevention or reversal of chronic diseases.

The preventive nutrition era began in earnest in 1977 with the publication of the Dietary Goals for the United States by the Senate Select Committee on Nutrition and Human Needs. Table 1 includes a number of the other diet and health publications that were issued (also see Cronin and Shaw, 1988). Within the past year we have seen reports from the Surgeon General (HHS, 1988) and the National Academy of Sciences/National Research Council (NAS/NRC, 1989).

While these reports often use caution when discussing diet-health relationships which have not been verified by solid scientific studies, the publicity surrounding such reports often lacks the caution statements, and the results can mislead the public as to the soundness of the data. Clearly, there is danger in this approach to nutrition policy and education.

Whether the emphasis on preventive nutrition continues to outweigh biochemical function will depend on results obtained from appropriate animal and human research studies. Many key long-term nutrition-intervention studies are already under way to test the effects of supplementation of diets with specific nutrients on certain diseases such as cancer. We must wait patiently and hope for definitive results from these studies. As Harper (1988) put it, the specific interrelationship of dietary pattern and incidence of diseases "can be resolved only through rigorous application of the scientific method."

Future Research Opportunities
For the dedicated nutritionist, the future is rich with research opportunities. There are perhaps more unresolved than resolved issues relating foods, diets, and specific nutrients to health and performance of humans and animals. Before researchers pursue unanswered questions, we would be wise to read some of the classic nutrition papers from the past 50 years and note the careful application of proper scientific method in those works. As Munro (1986) pointed out:

We must emulate the spirit of Drs. Goldstein and Brown on hearing of their award of the Nobel Prize on October 15, 1985. Dr. Brown said on interview that, in their basic work on lipoprotein receptors, their goal has been to determine why diet has a determining role in atherosclerosis. No team of research workers could better demonstrate the resounding success of basic science as applied to a nutrition-related problem. Back to basics!

Table 2 lists a number of future emphasis areas for nutrition research. Many of these research opportunities require the scientist to have experience/expertise in other fields such as biochemistry, immunology, physiology, psychology, and toxicology.

It is quite clear that most major advances in the nutrition field in the future will be achieved through an interface with other scientific disciplines. We are reminded that in 1932 Fletcher suggested that nutrition was "cross-bred" in its origin and "related to practically every branch of biological science...." In the same regard, a successful nutrition researcher should be well versed in other biological or chemical fields.

The future should continue to provide exciting advances in our understanding of the impact of foods and diets on health. We will refine our understanding of the role of nutrients in the classical areas of growth, reproduction, and longevity and perhaps in nontraditional areas such as immunity, hunger, mood, and optimal human performance. The field has come a long way in 50 years, and

---

For the dedicated nutritionist, the future is rich with research opportunities. There are perhaps more unresolved than resolved issues relating foods, diets, and specific nutrients to health and performance of humans and animals.

---

Table 2—Future Emphasis Areas for nutrition research

<table>
<thead>
<tr>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinement of human dietary requirements</td>
</tr>
<tr>
<td>Biochemical function of nutrients</td>
</tr>
<tr>
<td>Preventive health/health claims</td>
</tr>
<tr>
<td>Nutrient bioavailability/content of foods</td>
</tr>
<tr>
<td>Nutrient interactions/toxicity</td>
</tr>
<tr>
<td>Control of satiety</td>
</tr>
<tr>
<td>Psychobiology/mood</td>
</tr>
<tr>
<td>Development of special dietary foods</td>
</tr>
<tr>
<td>Immune response</td>
</tr>
<tr>
<td>Genetic manipulation of plants and animals</td>
</tr>
<tr>
<td>Nutrition education</td>
</tr>
<tr>
<td>Public nutrition policy</td>
</tr>
<tr>
<td>Eradication of malnutrition worldwide</td>
</tr>
</tbody>
</table>

---

226 FOOD TECHNOLOGY—SEPTEMBER 1989
thoughtful, basic research will yield greater advances and a healthier population in the next 50.

References

The future should continue to provide exciting advances in our understanding of the impact of foods and diets on health.


The suggestions of Richard Forbes, Paul Lachance, John Milner, and Chris Poor during the preparation of this manuscript are appreciated.

—Edited by Neil H. Mermelstein, Senior Associate Editor

**LUPRAN™**

**THE NEW CHOICE IN DIETARY FIBER**

- 84% DIETARY FIBER, FOUR TIMES AS MUCH AS OAT BRAN
- CONTAINS SOLUBLE AND INSOLUBLE FIBERS
- LOW COST AND EXCELLENT SOURCING
- CREAM COLOR AND BLAND FLAVOR ALLOW MAXIMUM USE IN YOUR FORMULATIONS
- LESS THAN ½ CALORIE PER GRAM
- NO PHYTIC ACID AS IN CEREAL BRANS

LUPRAN is produced from the outer seed coat of the Sweet White Lupin bean. The fiber is micropolverized and steam processed assuring a high quality fiber source.

for more information call:
INTERNATIONAL NUTRITION & GENETICS CORP.
EDEN PRAIRIE, MN 55344
(612) 941-4525

or our brokers:
West Coast:
SARONI TRADING, Jim Foust
SAN LEANDRO, CA 94577
(415) 895-5681

Illinois Region:
TOUHY & ASSOCIATES
ELK GROVE VILLAGE, IL 60007
(312) 766-8754

For information circle 192

SEPTEMBER 1989 — FOOD TECHNOLOGY 227
Food Packaging in the IFT Era: Five Decades of Unprecedented Growth and Change

Theron W. Downes

Today’s food package is a versatile and multitalented performer. It is called upon to contain, protect, preserve, perform, communicate, sell, and more. Packaging touches the daily lives of all of us, but each of us conjures up a different image if asked to describe the term. Paine (1962) offered the following definitions of packaging:

1. A coordinated system of preparing goods for transport, distribution, storage, retailing, and use.
2. A means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost.
3. A technoeconomic function that minimizes cost of delivery while maximizing sales and hence profits.

Purchasing people tend to evaluate the purchase price of packaging materials, while production people are interested in the efficiencies and productivity of packaging materials and systems in the plant. Marketing, advertising, and sales people tend to view the package with regard to its potential to differentiate, to communicate, and often to add value to the product/package system under scrutiny. The traffic, warehousing, and logistics people tend to examine the efficiency of the packaging in the distribution segment of its journey from manufacturer to consumer. Some view the package as an art form, and others believe it offers cultural and historical insights.

To the food technologist and the food packaging professional, perhaps more than to any other specific group, packaging is a discipline based on fundamental sciences. The physical, chemical, and biological interactions of the package, the product, the filling and sealing system, and the environment produce a branch of scientific investigation which is still in many ways in its infancy. Packaging suppliers, converters, and machinery manufacturers conduct fundamental investigations into the properties of materials and matter in motion.

This article will review packaging from a historical viewpoint, look at some of the major categories of packaging materials, and examine how packages and packaging have changed during the 50 years of existence of the Institute of Food Technologists.

History of Packaging

Boorstin (1983) called packaging “one of the most manifold and least noted revolutions in the common experience.” Whether revolution or evolution is the more appropriate term, his point is clear. Packaging tends to be taken for granted when it functions properly by providing wholesome, high-quality, nutritious food products throughout the year. It is most likely to be noticed when the bag stretches instead of opening or the easy-open feature fails or the child-resistant feature is impossible to decipher by anyone other than a child.

Surely no one questions the fact that packaging has played a key role in the development of the food industry in the Western world in the 20th century. Improved agriculture and efficient production, processing, packaging, distribution, and marketing have led to a food supply in the United States which is the envy of the world. We spend a smaller percentage of our disposable income on a more varied and nutritious food supply than anyone else in the history of the world. Prior to this century, the distribution of food products was almost entirely in bulk, with concomitant spoilage, sanitation, and disease problems. Packaging, in its most fundamental form, serves to contain, to protect, to inform, and to assist in utilization of products. The most fundamental of the needs which packaging fulfills is probably containment. While not as important as the decision to stand erect or the opposable thumb, packaging was certainly a prerequisite for the change from a hunting and gathering style of life to a more stationary society characterized by nurturing and agriculture.

The beginning of commerce as we know it can probably be traced to the civilizations around the Mediterranean some 8,000 years ago and coincides with the development of pottery around 6000 BC. The early civilization around the Mediterranean depended upon pottery for the trading of wheat, wine, olive oil, spices, and other products needed to maintain the food supply. This may also be the era in which the package began to fulfill the function of communication through painting and decoration which were used to identify the contents and specify their use. The first metals to be used were lead, gold, and silver. These materials could be found in nearly pure form in nature and were soft enough to be pounded into foils and used as such for the packaging of food. The ability to produce and to shape glass evolved between 4000 and 3000 BC. Paper, already developed in the Far East, was independently developed by the Egyptians from papyrus reed, from which the modern English name derives.
It is intriguing to consider Napoleon as one of the early proponents of the more modern approach to food packaging in which a product/package system is considered, instead of the more narrow view that had prevailed. Certainly, the development of shelf-stable food products in hermetically sealed containers in the early part of the 19th century has to be considered as a major achievement in the history of food packaging.

Later in the 19th century, the industrial revolution fostered five important packaging advances.

1. The metal can for heat-processed foods.
2. The collapsible tube, originally intended for portrait paints.
3. The folding carton, a critical development on the path to the self-service supermarket as we know it.
4. The corrugated shipping case, which has almost entirely replaced the wooden container for shipping.
5. The crown closure, which provided an affordable and efficient method of hermetically sealing narrow-neck bottles.

The latter part of the 19th century saw the introduction and commercialization of the milk bottle and canned condensed milk, both of which surely played a role in the improvement of the quality of life through reduced disease in general and infant mortality more specifically. Also introduced and commercialized was the famous Uneeda Biscuit package from the National Biscuit Co. This protective package containing a consumer-sized quantity of crackers is often pointed to as the beginning of the self-service era which continues today. It is at least plausible to believe that the phrase "the bottom of the barrel" refers to the condition of crackers before consumer packaging.

The early part of the 20th century witnessed an explosion in the marketing of products in branded packages. A new field of design was emerging, and a whole new recognition of the potent power of the package as "The Silent Salesman" was being recognized. While the food industry produced some notable examples such as the "Black Magic" chocolate box of Rowntree in England, the
Food Packaging (continued)

coffee bags produced for A&P, and the Armour family of products in the 1930s, cosmetics and perfumes surely led the way. The best glass designers such as Baccarat, Lalique, and Sabino were employed to design scent bottles. These containers, often more expensive than the product itself when offered, now command prices of several hundred dollars at antique auctions.

It is almost axiomatic today to recognize that package design and graphics are fundamental to product differentiation on the shelf. The importance of establishing a link in the consumer's mind between a packaging design and the high-quality product contained leads to carefully planned promotional and advertising budgets.

Most of the packaging in the first part of this century, before the founding of IFT, was made of paper, paperboard, or tinplate. Marketers had little in the way of containers and systems to use to differentiate their products and therefore had to rely upon graphics. People recognizing the potential value of the package as a sales tool were mostly to be found in the tobacco and cosmetics areas. Philip Morris is thought to have been one of the first companies to recognize the importance of packaging within the overall business strategy for its products. It is ironic to note that today, half a century later, Philip Morris has become the world's third largest food company. Glass was starting to become an important packaging material at that time, with the added advantage of the consumer's being able to see the product, as well.

World War II, with its food and material shortages and the search for substitutes, probably marks the ushering in of the modern era of packaging. The five decades of IFT's existence have been marked by an exponential increase in packaging materials, forms, and systems for food products.

Packaging Materials

Many different types and combinations of materials are used for food and beverage packaging:

- Metals. The metals used in food and beverage packaging are steel, tin-plated steel, and aluminum. They most commonly appear as cans, or as foils in combination with paper and plastic in flexible packaging. Some small number of tubes and trays are used, but the above forms predominate. Metals are used because they are largely inert, provide barriers, and offer reasonable strength and formability. Abundant raw materials, recycling programs, and improved technology have helped to maintain the cost effectiveness of metals in food packaging.

- Often erroneously attributed to Nicholas Appert is the development of the tin can for preserved food. It is probable that Peter Durand in England was the first to actually seal and cook a food material in a vessel made of tin, while Appert did his initial work in glass. It was not until some 50 years later that Louis Pasteur discovered the principle by which this preservation occurred, and it took another 60 or 70 years for the development of the science of canning as we know it today.

- Probably no single individual deserves more of the credit for reducing the art of preserving foods by "canning" to the science which we know today than Dr. C. Olin Ball. While claimed as a food scientist or food technologist by many who hold that title, Ball was also a packaging man (he also worked on the development of the heat-sealable milk container).

- The convenient, year-round supply of food in three-piece sanitary containers requires a systems approach based on delivering the appropriate thermal process and producing a hermetically sealed package which will maintain the commercial sterility of its contents through the distribution system. It is often overlooked today that the three-piece sanitary food can, first with a soldered side seam and more recently with welded side seams or two-piece construction, was one of the first of the truly convenient food packages. Processing is built into the product, and preparation requires just reheating and/or adding water. The requirements for maintaining integrity

<table>
<thead>
<tr>
<th>Date</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>Boil-in-bags, tear-off aluminum ends for composite juice cans, plastic tubs for cottage cheese</td>
</tr>
<tr>
<td>1961</td>
<td>Spiral-wound composite juice cans, high-density polyethylene (HDPE) gallon milk jugs, HDPE bleach bottles, bulk pellatizing for glass bottles</td>
</tr>
<tr>
<td>1962</td>
<td>All-aluminum beer cans, aerosol antiperspirants, polyethylene-coated milk cartons</td>
</tr>
<tr>
<td>1963</td>
<td>Steel coffee cans with plastic reseal lids, plastic loop carriers for beer cans</td>
</tr>
<tr>
<td>1964</td>
<td>Shrink-wrapped corrugated fiberboard trays for canned goods, easy-open aluminum ends for beer cans</td>
</tr>
<tr>
<td>1965</td>
<td>Screw-off closures for beer bottles, Saran-coated cellophane for snacks, HDPE margarine tubes, cheese in polypropylene film, mouthwash in polyvinyl chloride (PVC) bottles</td>
</tr>
<tr>
<td>1967</td>
<td>Tamper-resistant closures for milk jugs, HDPE jars for institutional mayonnaise, laminated plastic tubes</td>
</tr>
<tr>
<td>1968</td>
<td>Plastic-foam egg cartons, clear PVC bottles for food</td>
</tr>
<tr>
<td>1969</td>
<td>Plastic cans with full-panel end for ham</td>
</tr>
<tr>
<td>1970</td>
<td>Large bottles for soft drinks</td>
</tr>
<tr>
<td>1975</td>
<td>Metallized pouches for coffee</td>
</tr>
<tr>
<td>1976</td>
<td>Bag-in-box for wine</td>
</tr>
<tr>
<td>1977</td>
<td>Polyester soft-drink bottles</td>
</tr>
<tr>
<td>1980s</td>
<td>Aseptic carton introduced in U.S., coextruded ketchup bottle, tamper-evident closures, gas absorbers, microwave susceptors, microwavable polymers, thermal processing and heat sealing of rigid plastics, controlled- and modified-atmosphere packaging</td>
</tr>
</tbody>
</table>
World War II, with its food and material shortages and the search for substitutes, probably marks the ushering in of the modern era of packaging.

during thermal processing and distribution are one reason that steel-based containers have dominated the market for commercially sterile, shelf-stable products.

The ability to take advantage of the elevated internal pressures (3–5 atmospheres) in carbonated beverages to provide structural rigidity and strength led to dominance by aluminum in the carbonated-beverage field because very thin walls could be used. Recent increases in aluminum ingot prices have been coupled with increasing research effort by the steel industry in response to competition from abroad. These pressures on the use of aluminum are producing the potential for some major inroads by two-piece steel beverage containers which can also now be produced with extremely thin walls for carbonated beverages. Five years ago, a prediction that steel would recapture significant portions of the carbonated beverage market would have been met with laughter in most circles, but it looks as if significant penetration will occur in the next few years.

Perhaps the most publicized and least successful introduction in the shelf-stable foods area has been the retort pouch, for which the United States has been the major market. The use of retort pouches in the United States has only been successful in the Far East and to a lesser degree in Europe, where the “cold Chain” allowing the distribution, storage, and use of frozen foods is not nearly as developed as it is in the U.S. Here, the consumer has found similar price/value benefits with frozen boil-in-bag packaging. The consumer rarely calculates the cost of frozen storage in the home into the price of a product. The absence of frozen distribution and storage in the Far East to a large extent explains the commercial success of the retort pouch in Japan and Taiwan and suggests that a great potential still exists in the developing world.

The retort pouch introductions in North America did lead to the development of significant time and money in the development of systems to produce and inspect for seal integrity, an issue still not as well understood with heat-sealed containers as it is with double-seamed cans or double-seamed metal ends on plastic packaging.

- Glass. The first manufacture of glass probably occurred in Asia Minor. It is thought that the use of glass goes back to 3000 BC and that its development as a package form occurred largely in Egypt and other Mediterranean trading nations. Prior to the modern era, glass was manufactured manually, and its use was therefore limited to expensive materials such as liquor and perfume. One of the first liquor manufacturers to recognize the value of a brand name put his name on his private glass liquor bottle in Philadelphia, Pa., in the 1840s. His name was E.C. Booz.

The ingredients for glass—silica from sand, calcium carbonate from limestone, sodium bicarbonate from soda ash, and traces of alumina and other minerals—are among the most abundant and least expensive on the planet. Like metals, however, glass manufacture requires consumption of large amounts of energy, mostly in the form of fossil fuels, to purify, melt, and form containers. Glass is largely inert and impenetrable by gases and water vapor. Interaction with products is limited almost entirely to small amounts of leaching of sodium or calcium ions from the glass; this is of little consequence in the stability of products to test market or regular distribution channels.

Over the years, skidded pilot systems from Cherry-Burrell have ranged from very basic to complex multi-function systems combining several process methods. Each has been completely engineered to the customer's specifications and delivered pre-wired, pre-piped and pre-tested — ready to go to work. Cherry-Burrell manufactures several types of heat exchange equipment, including plate, tubular (single, double and triple), scraped-surface, and steam incorporation. More important, our long history of system application engineering encompasses the complete range of process challenges: high-acid, low-acid, liquid, viscous, and delicate particulate.

To sample the process system capability that awaits your next new product project, call or write
for brochure SB-1512: Cherry-Burrell Corporation, P.O. Box 3000, Cedar Rapids, Iowa 52406 1-800-553-8867.
Food Packaging (continued)

food products but may be of some importance to the stability of certain pharmaceuticals.

Its inertness, lack of migration other than minor leaching, and clarity have led glass to be perceived by the public and by marketers as a high-quality package. Perhaps the ability to see the product is coupled in the consumer's mind with the idea that the manufacturers wouldn't let them see the product if they weren't proud of it.

The development of automated glass container manufacture by Libby and Owens, coupled with improved sealing and resealing capability and automated inspection, provided food marketers with an affordable, high-quality package. The total volume of food containers of glass and metal has continued to grow in the U.S., but market share has been decreasing. The market share for glass has also decreased in the beverage area, at least partly because of the extra weight of glass containers.

- Paper, Paperboard, and Corrugated. In dollar sales or total number of containers, this category is far and away the leader in packaging in the U.S. The U.S. is the world's largest producer of these products, and the basic raw material is renewable. In some ways, this category can be thought of as the backbone of the packaging industry, in that paper and board remain the best buy for the dollar for structural considerations. Paper is used because of its ability to accept printing well and provide an attractive surface, coupled with the amount of strength that it provides for its cost and weight. The corrugated container came into widespread use in the early part of this century, following some disputes among railroad owners, forest owners, and producers of wooden boxes. While clearly providing less structural rigidity than wood, the corrugated container did provide a combination of structural performance, cost, and weight that led to its domination of the distribution packaging category. In fact, so much of the manufactured output of this country is distributed in packages (75-80%), and the corrugated shipping container has such a high percentage of that market, that the corrugated industry is looked at as an indicator of the economy. Gross national product (GNP) and total shipments of corrugated have tracked together during business ups and downs during the last few decades. Milgrom and Brody (1977) drew a connection between the utilization of packaging and paper and per capita GNP around the world. While the extent to which utilization of packaging is causative or symptomatic of development is debatable, a strong case can be made for the importance of packaging in cash commerce and its close relationship to output in the industrialized world.

- Plastics. Plastics as packaging materials were virtually unknown at the beginning of the IFT era. Some celluloid eyeglass frames, some appliance parts made of phenolics, and knitting needles made of casein had been produced in the era prior to IFT. The discovery of polyethylene in 1936 and applications of polyvinyl chloride in the late '30s marked the beginning of a major shift in the way foods would be packaged.

World War II and the resultant shortages in all materials led to major advancements in plastics and their application, as natural polymer sources were no longer available. At the beginning of the IFT era, plastic had an image that led to its usage at times as an adjective meaning artificial, and possibly inferior. During the ensuing decades, however, introduc-

The five decades of IFT's existence have been marked by an exponential increase in packaging materials, forms, and systems for food products.

ers how many polymers are used in conjunction with the closure systems in glass, the liners and enamels in metal, or the coatings on cartons containing frozen food or liquids, the expectation for continued growth in market share of plastics in food packaging seems self-explanatory. Plastics, plastics-containing coextrusions and laminations, and other composites are being developed on a scale which would have been unimaginable just a few years ago. There are literally thousands of primary materials and uncountable possible combinations. Buried platelets of barrier materials, glass-like coatings on polymers, and surface fluoridation for barrier and compatibility are some of the more-recent developments. Environmental considerations may shift this prognosis, as will be discussed later.

Developments in Technology

The most important technological developments in the field of packaging during the IFT era have probably occurred behind the scenes and largely unnoticed by the public. Some of the key developments are listed in Table 1; most are in the realm of the consumer.

During the 1950s and '60s, improved efficiencies of production, lightweighting, and downsizing led to the consumer price index for packaging's remaining largely below 100 through the OPEC embargo of 1974. In other words, the cost of packaging was decreasing relative to total food expenditure or disposable income during this period. Lighter-weight steel, ribs to add strength, better glass distribution, introduction of polymers, lightweighting of papers, and improvement of barrier properties were all leading to less material required per container, and packaging lines were operating at ever greater efficiencies and speeds.

Today, computer applications are having a similar impact on improved efficiency and reduced cost. Computer-assisted design and computer-integrated manufacturing are typical applications. Programmable controllers are reducing downtime and improving efficiency on more and more production lines. Machine-readable codes and information-management systems are changing the way packaging is viewed. The ability to measure direct product costs and direct product profitability is leading to growing awareness and understanding of the role of packaging in sound business planning.

Some technologies seem not to have the "sizzle" that catches the tech-

234 FOOD TECHNOLOGY—SEPTEMBER 1989
nologist's or marketer's eye, yet they play a major role in industry. Coextrusion, copolymers, and specialty resins are examples of such technologies. Others, like the retort pouch, are expected to change the face of an industry but rarely do. Irradiation, aseptic packaging, and controlled- and modified-atmosphere packaging are three technologies presently being advocated by some as the next technologies to change the face of packaging in the U.S.

- Coextrusion, whether for rigid containers, such as a squeezable, barrier ketchup container, or flexible packages, enables a supplier to marry the useful properties of various materials at the most economical thicknesses and combinations. The development of coextrusion is one of the key reasons for the continued growth of plastics in rigid and flexible containers. It also has the advantage of not requiring laminating solvents which have to be recovered or controlled because of environmental considerations and regulations; this adds to the economy of coextrusions.

The bag-in-box for wine, which was introduced in the 1970s, uses a coextruded bag and provides an interesting backdrop for a discussion of the interface of packaging science, technology, and the market. For many wines, the major mechanisms of degradation relate to oxidation catalyzed by light. With the larger (1-, 2-, and 5-gal) rigid container sizes, therefore, repeated dispensing from the container is involved, and more air is introduced with each use. Packaging the wine in a bag in an opaque box is ideal because the box prevents light transmission and the bag will collapse without allowing air to be introduced. Clearly, this package provides technical superiority from the standpoint of protecting the contents and delivering a high-quality product. Nevertheless, it is unlikely that people would be interested in buying expensive, fine wines packaged in a bag-in-box. Numerous studies have shown that fine products such as wine are expected by the consumer to be in certain types of packaging, with the shape of the glass bottle and the type of label and closure playing an important role in the consumer's perception of product quality. It is probable that fine wines could not effectively be sold with plastic closures, even though the plastic might outperform cork for some products.

- Irradiation seems destined to be rediscovered by every new generation of food and packaging technologists. It provides a very reliable method for producing shelf-stable products in hermetically sealed containers. The organoleptic quality of the product contained is another question. Irradiation utilizes very small amounts of energy during sterilization; it has been estimated that the energy absorbed in a sterilizing dose of ionizing radiation is the equivalent of raising the temperature of the product less than 5°F. The mechanism of action—production of free radicals and chemical interaction of those free radicals, resulting in destruction of the viability of organisms—also produces a number of off-flavors and off-odors which can reduce acceptability. There are also known color and texture effects.

The major advantage of irradiation is the ability to irradiate in a closed container, so that the manufacturer has close control over the integrity of the finished package. These advantages have led to irradiation's being the treatment of choice for medical devices and various types of implants and instruments for surgery. Irradiation is also routinely used for sterilization of containers for bulk aseptic systems, as well as for modification of polymer properties. The energy levels involved in irradiation are well below those required for any radioactivity to be induced in the materials being irradiated. None of the above facts will make much difference to the individual consumer, however, and the well-known phenomenon of NIMBY— "not in my backyard"—makes major increases of irradiated food in the U.S. unlikely in the near future.

- Aseptic Packaging, whereby shelf-stable products are produced by sterilizing the product and the packaging material or container separately and filling in a sterile environment, has been described by some as the...
Irradiation, aseptic packaging, and controlled-atmosphere packaging are three technologies presently being advocated by some as the next technologies to change the face of packaging in the U.S.

any price one had to pay. Kopetz (1984) told of a myth, prevalent in medieval Europe, of a “magic table.” Any knight who was pure of heart and mind could stand before the table and call upon it to fill itself with bounty, whereupon the table would be covered with fruits and vegetables, meats and preserves, drink, etc. Such a magic table could only be imagined in the absence of the preservation and packaging techniques which exist today. But Kopetz’s point was that the food industry and food packaging profession have turned every table into a magic table which can be filled with bounty year round.

Traditionally, packaging has too often been thought of as a necessary evil by the food manufacturing firm. Cost-cutting programs are very well known to the package development engineer in the food industry. Today, however, this attitude is evolving into an understanding that packaging is inseparable from quality perception and business strategy. The microwave oven and modern educated consumers who value their time have led to a consumer who is willing to pay for value added in packaging.

As the food industry examines how to establish and maintain a competitive advantage in an increasingly competitive marketplace, certain facts are becoming more clear: Within any given product category, there can only be one cost leader. Therefore, the bulk of the players in the game must choose to differentiate. That which makes a product different must be valued enough in the marketplace to cover the cost of being different.

There is certainly no doubt that the successful strategies in the 1980s have been evolving toward an understanding that it is not possible to separate the product and the package in the food area but rather that the value perception will be closely linked to
Calculated school and its form and functionality. In some cases, value added will be in the package itself, in terms of dispensability, squeezability, reusable ability to be heated in either a microwave or conventional oven, or ease of reheating or use.

To be different on the shelf, the package and the product together must maintain and communicate a value perception. Never in the history of the food industry has the understanding of quality packaging and a total systems approach been more important to success. I believe that the focus should be neither the product nor the package, but rather the product/package system.

Regulation and the Environment
It is probably not purely coincidental that the Institute of Food Technologists was established shortly after the passage of the 1938 Federal Food, Drug, and Cosmetic Act. While this law laid the basis for a modern era of food and food packaging regulation, it was not until the 1958 Food Additives Amendment that its major impacts were felt.

Prior to 1958, the government had to demonstrate a lack of safety or a potential problem of toxicity in order to take action against a product on the market. With literally millions of different potential product/package combinations, it is obvious that the resources at the federal level were simply not available for a close monitoring of the food supply.

The 1958 amendment required manufacturers to demonstrate the safety of product/package systems before they could be introduced into interstate commerce. This shifting of the burden of proof of safety from government to the industry is accepted by most as one fundamental leading to a food system which is arguably the safest and most affordable that the world has ever seen.

Unfortunately, our knowledge of both nutrition and toxicity is too limited to provide definitive answers to many of the questions which face us. Among the most critical questions is, how does one extrapolate data from long-term, high-dose ingestion or exposure in animals to safety in human beings? When the amendment was written, Congressman James J. Delaney included a clause which prevented the approval of any additive which had ever been shown to cause cancer in man or animal. (It is interesting that the Delaney clause also contained the first exception to itself).

At the time of its passage, the Delaney clause was arguably appropriate. Our analytical capability for detecting substances was such that it was possible to have toxic substances in the food supply at levels at which they might produce harm but which were too low to be detected by then available means. Under such circumstances, a strong case can be made for preventing the addition of any such material to our food supply either directly, or indirectly in the packaging material. With each passing decade, our analytical capabilities roll back more zeros on our ability to detect substances. We now detect nanogram, picogram, and lower levels of materials, where only milligram levels were detectable before. Under present analytical capabilities, it is unreasonable to continue to apply the Delaney clause to substances of known toxicity present at levels so low that it was clearly not the intent of Congress for the Food and Drug Administration to regulate them (Rosenthal, 1977).

It is the contention of many that the regulatory environment in the U.S. places us at an economic disadvantage with regard to foreign producers. Clearly, FDA can be shown to have been extremely slow with regard to approvals for food systems and drug...
systems, compared to other countries. But it is hard to accept that the years of delay before granting approvals for aseptic packaging and the retort pouch were due only to concerns over residual hydrogen peroxide or adhesive migration. I believe that it is unfortunate whenever adversarial relationships arise between regulators and the industry. It is clear that the goal of a safe and wholesome food supply is shared by both the food manufacturer and the regulator. The differences of opinion revolve on whether to select $10^{-12}$ or $10^{-10}$ as the safety criterion.

**Education and Professional Development**

Whether packaging is an industry, a profession, a discipline, a science, a technology, an art, or some combination of the above is an interesting topic for debate and discussion. Whatever position one would take, it is clear that there is growing recognition of the importance of sound science and technology in food packaging.

Brody (1988) observed that the original organizers of IFT included several professionals from the packaging industry. Food packaging and food technology were intimately interwoven in those early days. This interdependence was further emphasized with the establishment of the Food Packaging Division of IFT in the mid-1970s. The first symposium presented by the probationary Food Packaging Division was probably the first exposure in any depth for many in the audience to the new possibilities for aseptic packaging in containers other than metal and glass. Aseptic packaging in flexible and semirigid heat-sealed containers is a prime example of an area where cooperation among food and packaging professionals is vitally important to the future health and safety of our businesses and our customers. The dialogue can and must continue. The most critical need is for a systems approach to investigation and evaluation of food product/package systems. There is a continuous need for discussion among suppliers and users, materials specialists, and food producers.

Since the mid-1980s, the symposia offered by the division have usually been standing-room-only in rooms designed for more than 500 occupants. Membership in the division now totals more than 1,000 people joining together for the advancement of food packaging science and technology. This group of individuals is probably the largest single group of professionals in food packaging which can be identified anywhere in the world. It is clear that there will need to be improved professionalism and understanding of packaging as a key component of the food system as we progress into the future.

**What's Ahead**

Most definitions of packaging have overlooked, or at least failed to clearly state, the importance of a truly total systems approach. Because it is an external cost, little attention has been paid to reclamation of packaging materials at the end of their service life as packages. At the beginning of the IFT era, food packaging was rarely condemned because of its negative impact on the environment. As we celebrate IFT's 50th Anniversary, we cannot overlook the fact that one of the largest concentrations of food

---

**Detect E. coli before you can say 4-Methylumbelliferyl-β-D-glucuronide**

Well...maybe not that fast. But when traditional tests for the presence of E. coli often take a week or longer, Marcor's overnight MUG (4-Methylumbelliferyl-β-D-glucuronide)* testing reagent seems awfully fast.

How does it work? Almost all strains of E. coli produce β-glucuronidase, an enzyme which hydrolyzes MUG. The result is 4-methylumbelliferone, a fluorogenic product which can be easily detected under long wave UV or 366-nm light. When MUG is incorporated into a modified MacConkey Agar or Lauryl Sulfate Broth, seeded with a single E. coli cell, fluorescence is usually detectable in 12 to 20 hours.

Plan now for future QC speed and economy. Perform both gas production and fluorescent tests simultaneously, and compare the results. For recommended test procedures and complete product specification, Marcor is just a phone call away.

---

*Manufactured for Marcor by Genzyme Corp.

For information circle 211
Food Packaging (continued)

packaging professionals in the world exists within IFT. As landfill becomes more expensive and unavailable and as alternatives such as reclamation, recycling, recovering energy, etc., are utilized, it is incumbent upon this group of professionals to act responsibly with regard to the total environmental impact of our decisions and strategies.

As has so often been the case within our discussion of packaging materials and types, perception can be as important as fact. Degradability of one form or another is thought to be a significant advantage for packaging materials. Closer examination by those who are most engaged in waste management indicates that this is not the case. Degradability is incompatible with landfill in that it takes too long, for all practical purposes, and leads to the potential for groundwater contamination, toxic runoff, etc. Degradability essentially attacks what is literally and figuratively the tip of the iceberg—litter. Litter both on land and at sea may perhaps be ameliorated by the use of some degradable types of packaging. It is, however, only a tiny fraction of the solid waste problem. Packaging is both a contributor to the solid waste as it appears in our garbage and a contributor to reduction of solid waste by minimizing the amount of waste material which has to be transported.

It is rare for there to be any simple answers to the most appropriate use of packaging, when the total environmental impact of all energy and resources consumed during manufacture, production, distribution, and post-consumer disposal is included. It seems obvious to me that the most environmentally friendly packaging systems will consist of a mix of materials, including metals, glass, paper, and plastic, each used where it is most efficient, together with a mix of post-consumer reclamation techniques, including recycling, refiltering, reclaming, recovering, and reforming.

As this article goes to press, more than 256 bills are being considered by 35 legislatures in the U.S. Two things appear clear as we face these challenges: We will need to build on and improve cooperation and professionalism in food packaging, and we will need to speak out and to convince governments that a unified legislative approach at the federal level is required; otherwise, without the kind of concerted effort and total systems approach which will be necessary to preserve and protect our environment, the myriad of piecemeal approaches at the state, county, and municipal level will erode our economic well-being and competitive advantage.

A unified legislative approach at the federal level is required [because] the myriad of piecemeal approaches at the state, county, and municipal level will erode our economic well-being and competitive advantage.

References
Ideas, revelations, and opportunities and the changes they produce are unparalleled in human history. They are occurring in every segment of our society and have permeated our institutions. The food processing industry is no exception in sharing in these changes. When one considers that more than half of all scientists ever born are alive today and that progress in understanding our physical world is occurring at an ever-increasing rate, it is inevitable that there will be significant changes both macroscopically and microscopically in the food industry.

The food industry developed largely as a result of forces generated by the progressive nature of man. Canning discoveries by Durrant and Appert were responses to forces for industrialization stemming from the development of towns and the movement from agrarianism to industrialism. Survival of the species under these new conditions would require a food system which would support the population. In addition, military leaders such as Napoleon enlisted the help of science to feed their armies.

For eons of unrecorded history and for millennia of recorded history, there were small but significant developments in food preservation. Cheesemaking, breadmaking, brewing, fermentation, pickling, salting, and drying were food preservation processes which were discovered and improved through unorganized, unsophisticated, and serendipitous occurrences. Approximately a century and a half ago, increased food availability fostered the industrial revolution. According to Toffler (1980), computers and information processing will lead to the third revolution—from agrarianism and industrialism to individualism. Survival of the species under these new conditions would require a food system which would support the population. In addition, military leaders such as Napoleon enlisted the help of science to feed their armies.

This article will highlight some of the food processing advances that will drive this revolution for the food industry.

50 Years of Processing Advances

This year, we celebrate the 50th anniversary of the founding of the Institute of Food Technologists. During its lifetime, from 1939 to 1989, there have been significant developments in food processing (Table 1).

The 1930s saw the great depression and the adoption of mass production and mass markets which the auto industry initiated and championed. Wooden boxes, crates, and barrels gave way to lighter-weight fiber crates and plastics for transporting products. Cellulose packaging was introduced, along with the gable-top, waxed milk carton. New items on the store shelf included sliced bread and frozen foods. Air conditioning of plants meant that dried products could be prepared, packaged, and ultimately distributed. Products such as Jell-O came into the market because of these advances in process technology. Mass production meant mass movement of materials in plants, and improvements in conveying led the way. The consumer, spurred by reports of unsafe food practices, heralded the developments in food law which resulted in the enactment of the Federal Food, Drug, and Cosmetic Act of 1938. In 1939, the food industry was gearing up for mass production and mass markets.

The 1940s and the war years increased the emphasis on automation. There existed a large unskilled labor market and a tremendous demand for mass public feeding. This meant the mass production of frozen, concentrated, and dehydrated foods, using an unskilled labor force. Thus, automation was essential, and containerized handling became the norm, in order to ship products across the oceans to the military and the Allies. The vending machine was introduced at this time and held promise.

The 1950s saw the introduction of television and the home food freezer (independent of the refrigerator). These two innovations resulted in a tremendous change in food processing. Frozen dinners and foreign foods became widely accepted. Frozen ready-to-eat bakery goods were utilized by the working housewife. She was able to get out of the house and join the working force because of technological advances in producing higher-quality products for her family. Because of increased prosperity, target marketing was introduced, and the food industry took advantage of it by introducing a large number of products. Toward the end of the decade, the need for food for bomb shelters resulted in advances in technology for producing long-shelf-life foods.

The 1960s saw improvements in product quality due to advances in technology. Freeze drying and freeze-dried coffee hit the market and took it by storm. Computer control in the plant was introduced and promised improvements in product quality and efficiency. Rigid and flexible plastic containers were introduced into the refrigerator display case in the supermarket. Many new ingredients such as oil blends and flavoring agents were developed to produce new food products. Proteins from fish, whey, soy, and other sources were used to produce architectural, engineered, and formulated foods. The clean-in-place approach produced improvements in plant sanitation, ultimately resulting in improved products with a longer shelf life. Foam-mat drying and other drying techniques dramat-
ically improved the taste of dried milk powder. Utilization of enzymes in food processing produced unique products. Automation developed very rapidly for plants producing single products such as beer, milk, and baked goods. However, for large, multiple-product plants, instrumentation was not reliable enough for total automation, and developments were slow to come in that area.

By the 1970s, the era of cheap energy was over. By 1974, most plants had instituted energy-saving processes and had reduced energy consumption by at least 25%. Health foods and organic foods appeared with greater regularity on the store shelf, and new, small-scale processors were competing with the large manufacturers. There were promises of new food products from restructured materials which ultimately did not appear. Improved ingredients helped the food industry but did not radically change it. By the end of the 1970s, new, small, easy-to-use, environmentally robust computers were introduced into the plant. These allowed automation and better control of processes, especially for energy utilization. Membrane-processing systems for changing the characteristics of food fluids were introduced and commercialized for utilization of by-products from the food industry.

The 1980s saw a significant optimism on the part of the food industry and a significant distrust of the food industry on the part of the consumer. By 1981, aseptic processing was widespread in Japan and Europe, and there was increased pressure to adopt this technology in the United States. The consumer put an increased premium on product quality, and this resulted in a new generation of "upscale" products. Gourmet products were in, and food processors took advantage of improved freezing systems, frozen distribution, and retail and home freezing to introduce frozen entrees.

This historical review leads to two questions—what are the possibilities for further significant developments in food preservation processes, and where is the food industry going, driven by the consumer and regulation?

Driving Forces for New Technology

Initially, the prerequisites for a food preservation process were to produce (1) a "safe" product and (2) a food which would have a shelf life such that a person could survive from the end of one growing season to the earliest harvest.

In the past, adoption of new technology . . . was motivated primarily by reduction in cost and improvement in yield. Today, technology is also being adopted because of opportunities in market segmentation . . . regionalization . . . and increased product quality.
of the next growing season. Variety, nutrition, and eating quality were not considered as important as safety and shelf life. Today, there are several bases for adopting food preservation technologies. These include not only the capability of extending the shelf life of the product and delivering a safe product to the consumer but also safety, nutrition, cost, and quality. The cost function used to justify adoption of a technology includes not only the actual cost of labor, energy, waste treatment, and packaging but also the cost of marketing the perceived consumer benefits of the preservation process.

In the past, adoption of new technology by the food processing industry was motivated primarily by reduction in cost and improvement in yield. Today, technology is also being adopted because of opportunities in market segmentation ("niche marketing"), regionalization of products, and increased product quality. The food industry is aggressively seeking preservation technologies which deliver products to the consumer which "appear" to be fresh (Malkki, 1987). Because of changing lifestyles (two working members per family, etc.), the consumer is also demanding "chef-like" products.

Thus, the consumer presents a dichotomy to the food preservation industry. On the one hand, the consumer wants products with minimal processing and fresh-like characteristics. On the other hand, the consumer is willing to pay a premium for chef-like products which are highly processed. In both cases, the food marketing system wants to minimize the visibility of manufacturing. Consequently, "invisible" manufacturing will increasingly become a criterion for adoption of new technology. "Invisible manufacturing" is defined as those manufacturing techniques which are applied to produce consumer-ready products which appear to be minimally processed.

Quality and fresh-like/chef-like characteristics of food products are undoubtedly strong driving forces for adoption of new preservation technologies. To apply this principle, it is imperative to increase our basic understanding of factors affecting death and inhibition of microorganisms. This was identified as a critical research priority by the Institute of Food Technologists' Committee on Research Needs (Liska and Marion, 1985).

The cost function for manufacturing is also an important consideration. There are two elements in the cost function which could significantly increase cost and yet be readily accepted by the consumer. The first cost element that is receiving increased consumer and regulatory scrutiny is packaging. Returnable, recyclable, and/or biodegradable packaging material is essential for the future, and the consumer appears ready to accept increased cost to ensure a reduction in environmentally unsound packaging. The second significant cost element for which the consumer appears ready to pay a premium is minimization of waste generation and water utilization.

Another significant consumer-driven force for adoption of changes in preservation technologies is the desire to reduce chemicalization of our food. The consumer would prefer to see an increase in physical processing with a concomitant decrease in "chemical" processing.

The Need for Basic Knowledge

Although there is a non-zero probability of a serendipitous occurrence which would result in significant advances in food preservation processes, scientists and engineers must rely on the scientific method. This requires that we understand the nature of the problem, the nature of the materials, and the physical and chemical laws governing the processes. Spoilage factors for food products include microorganisms, enzymes, chemical reactions, pests, and mechanical damage (Farkas, 1977), and mechanisms of preservation include mechanical (including packaging), chemical, and physical (including heat, dehydration, irradiation, and high pressure) phenomena.
Food Processing (continued)

To systematically study and evaluate preservation strategies, it is essential to understand the nature of raw materials, including their variability and properties. This applies to intact plant and animal tissues as well as to ingredients isolated or derived from them. It is essential to understand not only their physical and chemical properties but also the properties perceived by the consumer (i.e., their sensory properties). It is intriguing, for example, to use protein in a unique physical form as a substitute for fat, as NutraSweet Co., Skokie, Ill., does with its new product, "Simplesse" (Anonymous, 1988). Coupling our knowledge of raw materials with knowledge of spoilage factors will allow us to apply physical and chemical principles to preserve high-quality food.

Significant advances can be made in “hurdle technology,” as proposed by Leister, in which a series of barriers to spoilage factors are combined. Pivnick and Petrasovski (1973) include the concept that inhibition is as important as destruction of microorganisms. In this strategy, any one of the barriers by itself would not protect the product, but the sum of the barriers provides the necessary protection.

Advances in packaging—including interactive packages (in which the package contains chemicals for preservation or scavengers of water and/or oxygen), modified and controlled atmospheres, and controlled release through encapsulation—will offer significant improvements in preserved foods (Karel, 1982). Biotechnology, with its potential to produce “natural” additives and “good” microorganisms through genetic engineering, obviously has tremendous potential in the food industry. Our understanding of the effects of high pressure and lasers on food ingredients and spoilage factors will lead to new developments in preservation.

Requirements for Advances in Food Manufacturing

If significant advances are to be made, however, it is increasingly apparent that the food industry must abandon the concept of “food processing” and embrace the concept of “food manufacturing.” When the food industry was primarily handling food commodities, it could be considered a processing industry. However, today the food industry is converting food ingredients from a variety of sources into finished, manufactured food products. The food industry has moved from the concept of “mix, process, and package” to a significantly more sophisticated manufacturing industry, and it relies on adopting technology which has first been applied in other high-technology industries.

As industry converts from a processing orientation to a manufacturing orientation, it becomes apparent that information is required in three essential areas: (1) chemical, physical, and transport properties, (2) automation, and (3) unit operations:

- Chemical, Physical, and Transport Properties. In the past 15 years, there has been significant improvement in understanding the chemical, physical, and transport properties of raw and finished food materials. Chemical and physical rate processes ultimately govern the efficiency of our unit operations. In many cases, models have been developed for the dependence of chemical, physical, and transport properties on macro- and microenvironmental and compositional factors (Okos, 1986; Jowitt et al., 1983). These properties are more complex for foodstuffs than for feedstocks and products in the chemical process industry because of the heterogeneity, anisotropic nature, and biological activity of foodstuffs. However, complexity of materials is no excuse for not conducting research which will yield an understanding based on thermodynamic consistency.

Today, with the help of numerical methods and computers, it is possible to develop models based on empirical correlations. However, correlations without thermodynamic consideration and foundation are useful only in very specific circumstances (Rotstein, 1988). Models based on thermodynamic and structural considerations will allow us to translate from one system to another to predict behavior. In addition, these models will yield mathematical forms which can subsequently be used in simulation of unit operations and processes.

- Automation. The food industry is currently in a state of flux. The advantages of automation are apparent, but the nature of food products does not permit widespread adoption of automation techniques used in other industries. Research must be done to facilitate adoption of flexible manufacturing systems, computer-integrated manufacturing, robotics, and vision systems. Automation requires sensors for on-line measurement of properties (chemical, physical, and microbiological).

There is another significant point of departure between automation applied to other industries and that applied to the food industry. In other industries, automation has been widely adopted to improve reliability and replicability. That is, each unit should be exactly identical to every other unit. For “chef-like” products and prepared foods, automation will lead to more consistent quality. However, for food products which are manufactured to resemble natural foodstuffs, each unit should have its own individual characteristics reflecting biological variability; complete uniformity is not desirable. Thus, the food manufacturing sector is faced with the dichotomy of automating for a consumer who wants “homemade” and “natural” products. Consequently, the industry is challenged to introduce some randomness into an automated system to mimic “homemade” variability. An example of this controlled heterogeneity is the production of the tube egg, in which the yolk is deliberately offset from the geometric center, since the yolk in “homemade” boiled eggs is rarely located in the center of the egg white.

- Unit Operations. The third essential element for making significant advances in food manufacturing and preservation processes is a thorough understanding of the unit operations applied to products. Even today, there is a lack of understanding of some of the most ancient unit operations applied to food products. In mixing, for example, most correlations for scale-up do not apply to food materials because of nonuniformity of raw materials and sensitivity of raw materials to shear. Other unit operations which require increased knowledge are separation operations (e.g., using vision systems and physical separations to produce desirable components); heat- and mass-transfer operations (i.e., fouling and cleaning, extrusion, drying, electroconductive and microwave heat transfer, non-Newtonian characteristics, freezing; membrane processing and
bioprocessing (including enzymes, whole cells, and cell homogenates); irradiation; and high pressure.

On the Threshold of a Revolution

At the end of 50 years of IFT’s existence, the food industry is on the threshold of a revolution. It is adopting and adapting strategies from other manufacturing systems which require fundamental information on the chemical, physical, and transport properties of materials, application of automation, and increased understanding of unit operations. Development of improved and new technologies for food preservation will depend upon the concept of destruction and inhibition of microorganisms and enzymes, and control of chemical reactions. This will require significant research on water relations in foods, sensors, properties of materials, material handling, and package/product/process interaction. The Institute of Food Technologists has a significant role to play in the next dynamic half century.

The role of the Institute as a forum for presenting research, its influence in increasing the quality of food science education, and its recognition by governmental agencies as the professional society for food science were essential contributions leading to the food industry of today. These and other activities need to be fostered as the food industry enters the 21st century.

References
—Edited by Neil H. Mermelstein, Senior Associate Editor

The proof is in the pudding!

Or the cake. Or the ice cream, cookies, chocolate drink… The proof that Gill & Duffus cocoa powders are the finest available.

Gill & Duffus cocoa comes in a wide variety of standard powders, from Natural and Lightly Alkalized to Red and Black. Or, let our professionals custom blend a powder to meet your specific requirements.

Gill & Duffus cocoa powders. Because putting in quality means quality in pudding. Or whatever it is you make. Send or call today for a brochure and the name of your local representative.

1-800-257-8166

Gill & Duffus products
600 Ellis Rd., Glassboro, NJ 08028, (609) 881-4000
Send for free Brochure on Cocoa Facts!

For information circle 196
The Evolution of Sensory Science and its Interaction with IFT

Rose Marie Pangborn

Sensory analysis and the Institute of Food Technologists share a common history of development in the United States. Early founders of IFT strongly supported and encouraged development of the fledgling sensory field. Later, professional groups such as the American Chemical Society, the Society of Chemical Industry, the American Society for Testing and Materials (now ASTM), the International Union of Food Science and Technology (IUFoST), and others joined IFT in nurturing sensory science activities. The following partial chronology represents my view of some of the highlights in the development of this young discipline.

From Expert Taster to “Organoleptic” Analysis

Several noteworthy histories are available on the neogenesis of sensory analysis, ranging from T McGran’s (1971) erudite evaluation of international and interdisciplinary landmarks and Harper’s (1977) perceptive review of developments in the United Kingdom, to Pangborn’s concatenating summaries and laments (1964; 1979; 1980; 1981; 1984a; b; 1987).

The establishment of IFT in the late 1930s coincided with brave attempts to apply the knowledge and experience of “expert tasters” (tea, coffee, wine, dairy products) to the array of new foods which were being processed. It was soon realized that it was not feasible to have an expert for every commodity. Furthermore, it was risky to base go/no-go decisions on the judgment of one person; hence, the development of panels of trained judges. However, much time and effort were lost in treating employee panels as if they were miniature consumer groups and measuring preferences in the futile hope that they would reflect behavior of the ultimate product users.

King’s (1937) article in Food Research represents one of the first attempts to distinguish between preference and discrimination testing. The classic review of difference tests and simple scaling by Boggs and Hanson (1949) constitutes one of the first formal approaches to more reliable and scientific sensory testing, i.e., the use of trained judges to quantify differences and perceived intensities.

Several occasional users (and misusers) of simple sensory tests for product assessment still refer to their studies with the picturesque but archaic term “organoleptic” —to judge with the organs. Since sensory receptors, not “organs,” respond to temperature, pain, touch, pressure, as well as to the chemical stimuli, the more precise adjective “sensory” is recommended.

From the Kitchen to Sensory Analysis

In the 1940s and ‘50s, home economists worked with commodity specialists to assess sensory changes attributable to new varieties, processing variables, storage times, recipe alterations, etc. Hence, the association of sensory analysis with the pejorative, “girls in the kitchen.” The 1951 booklet by Dawson and Harris (Table 1) illustrates the large number of sensory measurements which developed along commodity lines.

A concomitant image was that of the “acceptance laboratory,” devoted to endless testing of hedonic responses of laboratory personnel. Noteworthy contributions in appropriate acceptance testing of servicemen, as well as basic sensory psychophysics, were made by Peryam and associates at the Quartermaster Food and Container Institute for the Armed Forces (see, e.g., Peryam et al., 1960), and have been continued by Meiselman, Cardello, and others at the U.S. Army Natick Research and Development Center.

Credit for early development of sound sensory and statistical procedures is due to investigators such as Sylvia Cover of the Texas Agricultural Experiment Station. Her many publications on sensory attributes of beef, as related to selected histological, chemical, and physical data, spanned from approximately 1936 to 1962 (see, e.g., Cover and Hostetler, 1960).

As former departments of dairy industry, meat science, foods, etc., merged into departments of food science at the land-grant colleges, sensory analyses of aromas and of textures began to be compared with, respectively, chemical (e.g., GLC) and physical (e.g., Instron) measurements. This led to the use of the term “subjective” analysis, with the implication of less reliability, in contrast to instrumental measurements called “objective” analyses. As Trant et al. (1981) noted, sensory judgments are derived from subjects and instrumental measurement from inanimate objects, but one cannot assume there is no subjectivity in the operation of instruments and/or no objectivity in sensory analysis.

ASTM (1967), Guadagni (1968), and Noble (1975) drew attention to the importance of appropriate sensory techniques for meaningful correlation with physical and chemical tests. The classic studies by von Sydow and coworkers on aromas of bilberries and of beef (see review by Pangborn, 1987) merit mention. They were among the first to present clear-cut relationships between gashromatography...
graphic separations, mass spectrometric identifications, and quality and intensity assessments by trained judges.

The emergence of descriptive analysis of flavor can be credited to consultants at Arthur D. Little, Inc. (Caul, 1957). Classification of food texture and development of descriptive terminology and corresponding physical attributes was researched extensively by Alina Szczesniak and coworkers at General Foods Corp. from approximately 1963 to 1985 (see, eg., Szczesniak, 1975). Her achievements brought her international recognition, including IFT's 1985 Nicholas Appert Award. Refinements in the application and quantification of descriptive techniques have been presented by consulting firms such as Tragon Corp. (Stone et al., 1980) and Sensory Spectrum, Inc. (Civille, 1987).

Various professional groups have focused on development and utilization of sensory procedures. IFT’s Sensory Evaluation Division, which was established in 1971 and now has 1,400 members, sponsors yearly symposia and circulates a quarterly newsletter. ASTM’s Committee E-18 has published many valuable guidebooks on sensory, methods, physical facilities, etc. The International Standards Organization also has been active in promoting sensory methods. The Sensory Panel of the Society of Chemical Industry, organized in London in 1974, sponsors one major meeting and other smaller ones each year. The American Chemical Society continues to sponsor and publish numerous symposia on taste and flavor applications and their measurement, e.g., the September 1988 conference on sweeteners in Los Angeles.

Paradoxically... the 50th anniversary of IFT coincides with side-by-side occurrence of nonexistent, underdeveloped, developing, and developed sensory analysis programs in both business and academia, nationally and internationally.

Over the past 20 years, several of the prestigious Gordon Research Conferences in New England have concentrated on gustation and olfaction and related psychophysical measurements, and their neurophysiological and chemical correlates. The European Chemoreception Research Organization (ECRO), which originated in France in 1972 and now has more than 350 members from 28 countries, publishes a quarterly list of references and a newsletter, and sponsors biennial international symposia in Europe.

The Association for Chemoreception Science (AChemS), concerned with the chemical senses across species, was founded in Florida in 1979 and now has
The Evolution of Sensory Science (continued)

approximately 350 members, distributes a biennial newsletter, and meets annually. The journal Chemical Senses is jointly sponsored by AChemS, ECRO, and the Japanese Association for the Study of Taste and Smell (JASTS), which was organized in 1966. The International Symposium on Olfaction and Taste (ISOT), which promotes cross-disciplinary exchange in the chemical senses, first convened in Stockholm in 1962, and continues to meet

Table 1—A Chronology of Major Books in sensory science, 1945–89ab

<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>Flavor (Crocker, 1945)</td>
</tr>
<tr>
<td>1951</td>
<td>Sensory Methods for Measuring Differences in Food Quality (Dawson and Harris, 1951)</td>
</tr>
<tr>
<td>1954</td>
<td>Food Acceptance Testing Methodology (Perry et al., 1954)</td>
</tr>
<tr>
<td>1957</td>
<td>Analiza Organoleptyczna Zywosci (Tilgner, 1957)</td>
</tr>
<tr>
<td>1958</td>
<td>Flavor Research and Food Acceptance (A.D. Little, 1958)</td>
</tr>
<tr>
<td>1965</td>
<td>Principles of Sensory Evaluation of Food (Amerine et al., 1965)</td>
</tr>
<tr>
<td>1967</td>
<td>Methods for Sensory Evaluation of Food (Larmond, 1967)</td>
</tr>
<tr>
<td>1968</td>
<td>Odour Description and Odour Classification (Harper et al., 1968)</td>
</tr>
<tr>
<td>1975</td>
<td>Zarys Analizy Sensorycznej Zywosci (Pikielna, 1975)</td>
</tr>
<tr>
<td>1977</td>
<td>Sensory Properties of Foods (Birch et al., 1977)</td>
</tr>
<tr>
<td>1978</td>
<td>Structure-Activity Relationships in Human Chemoreception (Beets, 1978)</td>
</tr>
<tr>
<td>1979</td>
<td>Sensory Evaluation Methods for the Practicing Food Technologist (Johnston, 1979)</td>
</tr>
<tr>
<td>1982</td>
<td>Food Texture and Viscosity, Concept and Measurement (Bourne, 1982)</td>
</tr>
<tr>
<td>1983</td>
<td>Sensory Quality in Foods and Beverages: Definition, Measurement and Control (Williams and Atkins, 1983)</td>
</tr>
<tr>
<td>1984</td>
<td>Statistical Methods in Food and Consumer Research (Gacula and Singh, 1984)</td>
</tr>
<tr>
<td>1985</td>
<td>Sensory Analysis of Foods (Piggott, 1984)</td>
</tr>
<tr>
<td>1986</td>
<td>Sensory Evaluation Practices (Stone and Sidel, 1985)</td>
</tr>
<tr>
<td>1987</td>
<td>Sensory Evaluation of Food. Theory and Practice (Jellinek, 1985)</td>
</tr>
<tr>
<td>1988</td>
<td>The Sensory Evaluation of Dairy Products (Bodyfelt et al., 1988)</td>
</tr>
</tbody>
</table>

See references for publisher

Does not include the excellent series of booklets published by ASTM’s Committee E-18 or proceedings of symposia published by the American Chemical Society, European Chemical Senses Research Organization, and International Symposium on Olfaction and Taste

250 FOOD TECHNOLOGY—SEPTEMBER 1989
The Evolution of Sensory Science (continued)

and publish proceedings every three years.

On the local level, Chemical Senses Day, an annual one-day symposium, was established in Northern California in 1983 to provide a forum for formal and informal interaction among students and established investigators in the broad area of chemosensory research.

The partial chronology of books on sensory topics given in Table 1 not only recognizes the pathfinders, but also illustrates the geographic and disciplinary distribution of sensory activity. Articles concerned with sensory method-

ology, physiology, and psychology were abstracted by Drake and Johansson (1969; 1974). They listed 2,000 references from 71 periodicals from 1950 and 1968, and 800 articles from 70 periodicals from 1969 to 1973.

Milestones can also be traced via the issuance of specialized journals for the growing number of sensory studies (Table 2). The first, Journal of Texture Studies, established in 1969, was the brainchild of the pioneering Alina Szczesniak, with Malcolm Bourne picking up the reins in 1979. More recently, Max Gacula Jr. developed the Journal of Sensory Studies.

Widespread Use Today

Today, sensory professionals trained in food science are applying their expertise to a wide variety of nonedible goods such as household products, personal-care products, tobacco, pharmaceuticals, etc. This imitation, the sincerest form of flattery, coupled with the ever-increasing number of employment opportunities at very competitive salaries, attests to the growing importance of sensory analysis of foods and other products.

Some universities have progressed from offering one lecture on "taste tests" in the quality control class to offering a Ph.D. in sensory science with an array of multidisciplinary courses. Nonetheless, the industrial demand for well-trained professionals at the B.S., M.S., and Ph.D. levels greatly exceeds the supply. Also, universities attempting to fill retirement positions or to initiate new programs in sensory science are encountering very few appropriately trained Ph.D. applicants. Unfortunately, the immediate future promises a continued shortage of sorely needed sensory professionals.

The industrial demand for well-trained professionals at the B.S., M.S., and Ph.D. levels greatly exceeds the supply. . . . The immediate future promises a continued shortage of sorely needed sensory professionals.

Table 2—Keynote Journals in Sensory Science

| Journal of Sensory Studies | A quarterly journal initiated in 1986 for the publication of original articles on sensory topics, including psychology, chemistry, physiology, psychophysics, statistics, computers, and related areas. Food & Nutrition Press, Inc., Westport, Conn. |

Many other journals also publish sensory research, including the U.S. publications Food Technology, Journal of Food Science (and corresponding journals of other countries), Journal of Agricultural & Food Chemistry, and Journal of the Science of Food and Agriculture, many food product and specialty areas journals, as well as various nutrition and pharmaceutical journals.

Most industries have moved beyond the omnipotent "expert" to sensory science departments (Table 3). Government activity has advanced from development of quality standards, some of which ignored sensory quality entirely (e.g., meat and poultry grading), to funding of sensory research through the National Institutes of Health, the National Science Foundation, the U.S. Dept. of Agriculture, the U.S. Army Natick R&D Center, and many other agencies. Private consultants in sensory analysis are much in demand in the United States and abroad, offering a dozen or so short courses a year.

Many food companies recognize that reliable sensory results are a vital tool for decision making in basic research, quality control, product development, consumer testing, and marketing. Most food research laboratories use advanced sensory methods—with attention to appropriate experimental design, sampling, judge selection and training, computerized data entry, extensive data analysis by univariate and multivariate statistical programs, and continual attention to reliability and validity. It is encouraging to see cross-disciplinary approaches to sensory measurement among teams of food scientists, psychophysicists, physiolo-

Today, sensory professionals trained in food science are applying their expertise to a wide variety of nonedible goods. [This] attests to the growing importance of sensory analysis. . . .
Table 3—Stages in Evolution of a sensory science program (industrial, government, private, or academic)

Stage 0: The Boss is Always Right
No sensory facilities. “Mr. Management” tastes everything himself
Products succeed or fail independent of sensory attributes

Stage 1: Organoleptic Analysis
Technicians untrained in sensory analysis
Small room for sample preparation and testing
Judges: Available building personnel; sometimes test products at their desks
No attention to test designs, sample coding, randomization
Use paired-preference, hedonic scales, ranking
Data analysis: Consult “Roessler” and “Kramer” tables
No measurement of reproducibility, validity, reliability
Management is neutral or tolerates sensory work

Stage 2: The Test Kitchen
Technicians have short-course background
Test room with simple booths
Judges: Building personnel, some screening
Simple test designs, sample coding, randomization
Use difference, preference, hedonic tests, some scaling
Data analysis: Chi-square, t-tests, correlations, two-way analysis of variance
Management provides qualified support of sensory work

Stage 3: The Sensory Analysis Laboratory
Laboratory manager has university training at B.S. level
Adequate preparation areas and separate testing rooms
Judges: Selected and trained building personnel
Use discrimination, scaling, descriptive analysis (work with marketing on preference and hedonic testing)
Appropriate test designs and procedures
Extensive parametric and nonparametric univariate statistics and use of computer programs
Management supports sensory work

Stage 4: The Sensory Science Department
Director of Sensory Sciences—M.S. or Ph.D. level
Extensive facilities: Several preparation, testing, and data-processing areas, fully computerized, full statistical services
Use appropriate sensory evaluation and psychophysical methods, designs, and univariate and multivariate statistical analyses
Extensive interaction with other scientists and other units—research, product development, marketing; thorough knowledge of company products and policies and of professional organizations, societies, journals, expertise in field
Conduct developmental sensory research and publish results
Take active leadership role in profession, internal and external
Management strongly supports and takes pride in sensory department, and encourages continuing education and development

The combined efforts of neurophysiologists, biochemists, and behavioral scientists will culminate in a better understanding of the mechanisms of taste and odor perception.
The Evolution of Sensory Science (continued)
short time.
Equally exciting is the expectation that the combined efforts of neurophysiologists, biochemists, and behavioral scientists will culminate in a better understanding of the mechanisms of taste and odor perception. This breakthrough will unleash not only a myriad of scientific advances, but will provide product developers with unlimited opportunities for customizing the sensory attributes of many consumer products.

Compared with other areas of food research, sensory science has considerably more “catching up” to do. Consequently, there will be many exciting challenges and rewards for the researchers of the future.

References
King, F.B. 1937. Obtaining a panel for judging flavor in foods. Food Res. 2: 207.

Compared with other areas of food research, sensory science has considerably more “catching up” to do. Consequently, there will be many exciting challenges and rewards for the researchers of the future.

—Continued on page 307
Foodservice as a means of feeding people away from home has its roots at least 3,500 years ago in Ancient Egypt, where "inns" provided food and drink to traders. The beginning of modern foodservice as we know it today can perhaps be traced to the development described in the following letter:

My Board of Arts and Manufacturers has reported to me, Sir, the examination it has made of your process for the preservation of fruits, vegetables, meat, soup, milk, etc.... and from that report no doubt can be entertained of the success of such process. As the preservation of animal and vegetable substances may be of the utmost utility in sea voyages, in hospitals and domestic economy, I deem your discovery worthy an especial mark of the good will of the government. I have in consequence acceded to the recommendation made by my council to grant you a recompence of 12,000 francs....

So wrote Mr. Montalivet, French Minister of the Interior, on January 30, 1810, to Mr. Nicholas Appert, a wine merchant, for his invention in 1809 of a means for preserving foods. As is well known, Appert's development of preservation of foods in sealed wine bottles was in response to Napoleon Bonaparte's need for feeding his vast armies in the field.

The historical development of foodservice as an industry is a fascinating one, as illustrated by the brief chronology of significant events in Table 1. This article will focus on the structure and scope of the foodservice industry; the influence of foodservice on the development of food technologies; the "push-pull" dynamics of the marketplace in which the foodservice industry operates and how those dynamics apply to the use of food technologies in foodservice; and the future of the foodservice industry.

Structure and Scope of Foodservice

Foodservice is a system whereby foods are primarily prepared and consumed away from home. According to the National Restaurant Association (NRA, 1988), the foodservice industry is divided into three groups:

1. Commercial Feeding. This group comprises establishments which are open to the public, are operated for profit, and may operate facilities and/or supply meal services for others. It accounts for more than 85% of industry sales and includes eating and drinking places, foodservice contractors, hotel/motel restaurants, and restaurants in department stores, drugstores, etc. Annual sales are estimated at slightly more than $202 billion (Table 2).

2. Institutional Feeding. This group comprises business, educational, governmental, and institutional organizations that operate their own foodservice. Food is provided as a complement to other activities, usually without the profit margins which exist in Group 1. Group 2 serves food principally as a convenience for employees, students, patients, etc. Annual sales are estimated at slightly more than $24 billion (Table 2).

3. Military Feeding. This group comprises food and beverages sold at officers' and NCO clubs and military exchanges, as well as the feeding of troops. Because of this group's uniqueness in specification and bidding requirements, it is treated as a distinct entity by most suppliers. Annual sales are estimated at slightly more than $1 billion (Table 2).

While the food and drink sales are estimated at a grand total of more than $227 billion for 1989, the total food and drink purchases by the foodservice industry (also shown in Table 2) are estimated at more than $285 billion for 1989.

Thus, the foodservice industry has evolved into a thriving business. In addition to its sheer size, the industry has captured a steadily increasing share of the consumer's food dollar over the past 50 years, although the overall per capita expenditure on foods has declined. According to data from the Census Bureau compiled by Technomic Consultants (1988), during the 16 years from 1972 to 1988, retail consumer expenditures decreased by 6% (from 58.1% to 52.0%), while foodservice consumer expenditures increased by 6% (from 41.9% to 48.0%).

Food Technology in Foodservice: An Old Friend Revisited

Commensurate with this growth, the evolutionary relationship of food technologies to foodservice is a very interesting one and is perhaps not well understood. One reason is that generally, we tend to equate foodservice only with limited-menu establishments (better known as fast-food restaurants) without regard to the other commercial and noncommercial sectors of the industry.

However, the influence of foodservice on the development of food technologies can readily be demonstrated in several areas:

- Nicholas Appert's packaging and preservation of meats, fruits, vegetables, and milk in breakable glass bottles for feeding troops in the field was to become the forerunner of...
the canning and packaging technologies. Appert’s discovery soon led to the development of unbreakable “tin” cans in England by Peter Durand, and in 1813 Bryan Donkin and John Hall began to can foods (using Durand’s patented method) for the British army and navy.

- William Underwood in 1819 (two years after his arrival from England) established a small canning plant in Boston, Mass. However, it was the Civil War in the U.S. that propelled the use of canning technology in this country and the acceptance of canned foods not only in the military but among explorers and civilians as well.

- With the further development of canning, the invention of retorting (or pressure cooking) in 1874 by A.K. Shriver in Baltimore, Md., enabled canners to control temperature accurately while cooking food in sealed cans.

- Similarly, the need to pack chop suey in No. 10 cans for restaurants led C. Olin Ball in the early 1950s to develop the Smith–Ball canning process for LaChoy. A modification of this process is still in use today.

- The pressing needs for feeding masses of both military troops and civilians during World Wars I and II, as well as the Korean War, led to such technological developments as dehydration, frozen prepared meals, and irradiation.

- Dehydration is as old as mankind. Yet not until we understood some of the specific changes which occurred during drying, storage, and deterioration, such as with the browning (Maillard) reaction, did dehydration become a feasible technology for preserving food quality. The vacuum drying of fruits and vegetables and freeze drying of meats, poultry, and seafood (especially shrimp) soon followed.

- Freezing of Foods for in-flight feeding was pioneered by Pan American World Airways, the first airline to use frozen prepared dinners during flight.

- Use of Ionizing Radiation for preserving foods at ambient conditions began some 37 years ago. The stimulus for these trials was the need to supply quality, shelf-stable foods at affordable costs to our military forces in Korea.

- The application of microwave technology in the food industry dates back to the early 1940s. However, in the early 1950s the Pennsylvania Railroad began to reheat chilled precooked foods for buffet-type service, and soon...
The Foodservice Industry (continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.D. 1200</td>
<td>A snack bar called “the Thermopolium” prepares and sells hot food and drinks to the people of Pompeii, Italy</td>
</tr>
<tr>
<td>B.C. 1280</td>
<td>Innkeepers in Florence, Italy, form an association to regulate its membership</td>
</tr>
<tr>
<td>1425</td>
<td>The Swan Inn of Lavenham, England, opens to travelers, eventually becoming one of the world’s best-known inns</td>
</tr>
<tr>
<td>1633</td>
<td>The first restaurant in the United States, a tavern in Boston, Mass., is opened by Samuel Coles</td>
</tr>
<tr>
<td>1809</td>
<td>Nicholas Appert, a wine merchant, preserves foods in sealed wine bottles</td>
</tr>
<tr>
<td>1848</td>
<td>August Escoffier, one of the world’s most renowned chefs, is born in France</td>
</tr>
<tr>
<td>1865</td>
<td>Bookbinders Restaurant, a landmark in the American foodservice industry, opens in Philadelphia, Pa</td>
</tr>
<tr>
<td>1876</td>
<td>Fred Harvey innovates foodservice in the transportation industry when he founds a company which services the entire Santa Fe Railway with restaurants at 100-mile intervals</td>
</tr>
<tr>
<td>1919</td>
<td>The National Restaurant Association (NRA) is founded</td>
</tr>
<tr>
<td>1920</td>
<td>The first NRA annual exhibition is held in Cleveland, Ohio, with 100 exhibitors</td>
</tr>
<tr>
<td>1925</td>
<td>Howard Johnson opens his first ice cream/drugstore/restaurant in Wollaston, Mass.</td>
</tr>
<tr>
<td>1940s</td>
<td>White Castle, one of the first fast-food chains, opens its doors</td>
</tr>
<tr>
<td>1950s</td>
<td>McDonald’s, Burger King, and Kentucky Fried Chicken open as fast-food restaurants</td>
</tr>
<tr>
<td>1960s</td>
<td>Home delivery of pizza and other limited menu foods begins to grow</td>
</tr>
<tr>
<td>1970s</td>
<td>Wendy’s popularizes drive-through windows</td>
</tr>
<tr>
<td>1980s</td>
<td>“Healthy” foods evolve as a major staple in foodservice operations</td>
</tr>
</tbody>
</table>

Table 1—Chronology of Significant Events in Foodservice

The foodservice industry has evolved into a thriving business. In addition to its sheer size, the industry has captured a steadily increasing share of the consumer’s food dollar over the past 50 years.

Meeting the Push–Pull Dynamics of the Marketplace

In the 1950s, the increased use of automobiles for personal travel coupled with the creation and subsequent expansion of the U.S. interstate highway system catapulted our society into high mobility. This mobility, in turn, created the need for more foodservice facilities in motels and bus and railway terminals and along the stretches of the newly built interstate system. Also, the “Graying of America” has dramatically stimulated the growth of the health-care segment of the foodservice industry.

With the U.S. population growth rate now leveling off at about 1% per year (compared to double that figure in the 1950s), foodservice companies no longer have the luxury of a natural market expansion. Growth must be achieved through innovative programs which will expand market share by fulfilling consumer wants and needs. Such needs, in turn, are fueled by such changing demographics and lifestyles as older population, increased number of women acquired specially designed dining cars and equipped them with microwave ovens. In 1955, the Kaiser Hospitals in California began the first full-scale foodservice operation using microwave ovens. The first line of microwavable prepared foods was introduced by Morton Foods Div. of Continental Baking Co. Similarly, although the Wilson Menu Pak pouches were used in conjunction with special electric heating apparatus to reheat them, Morton first used high-density polyethylene trays with heat-sealed polyester film covers for its line of individual-portion and bulk-pack entrees, vegetables, and starches.

- In 1960, Armour Co. introduced its Continental Cuisine line of gourmet entrees, intended primarily for an à la carte menu in a restaurant. These entrees were packed into a dual-compartmented pouch, one with the entree, the other with side dishes.
- The retort pouch was pioneered by the U.S. Army Research and Development Laboratories, Continental Can Co., and Reynolds Metals Co. It played a key role in the early feeding of astronauts in space.

By now, it is evident that the foodservice segment of the food industry has played an important role in the development of various food technologies. Although the military sector has had perhaps the greatest influence on such developments, nonmilitary segments such as restaurants, health care, and transportation have also made significant contributions. Today, sales from the commercial and institutional segments of foodservice have completely overshadowed those from the military sector (Table 2).

Two important forces at work in the marketplace have contributed to this nonmilitary growth—one is the consumer’s exerting a “pull” effect, and the other is the foodservice industry’s exerting a “push” effect.

- In 1960, Armour Co. introduced its Continental Cuisine line of gourmet entrees, intended primarily for an à la carte menu in a restaurant. These entrees were packed into a dual-compartmented pouch, one with the entree, the other with side dishes.
- The retort pouch was pioneered by the U.S. Army Research and Development Laboratories, Continental Can Co., and Reynolds Metals Co. It played a key role in the early feeding of astronauts in space.

By now, it is evident that the foodservice segment of the food industry has played an important role in the development of various food technologies. Although the military sector has had perhaps the greatest influence on such developments, nonmilitary segments such as restaurants, health care, and transportation have also made significant contributions. Today, sales from the commercial and institutional segments of foodservice have completely overshadowed those from the military sector (Table 2).

Two important forces at work in the marketplace have contributed to this nonmilitary growth—one is the consumer’s exerting a “pull” effect, and the other is the foodservice industry’s exerting a “push” effect.

Meeting the Push–Pull Dynamics of the Marketplace

In the 1950s, the increased use of automobiles for personal travel coupled with the creation and subsequent expansion of the U.S. interstate highway system catapulted our society into high mobility. This mobility, in turn, created the need for more foodservice facilities in motels and bus and railway terminals and along the stretches of the newly built interstate system. Also, the “Graying of America” has dramatically stimulated the growth of the health-care segment of the foodservice industry.

With the U.S. population growth rate now leveling off at about 1% per year (compared to double that figure in the 1950s), foodservice companies no longer have the luxury of a natural market expansion. Growth must be achieved through innovative programs which will expand market share by fulfilling consumer wants and needs. Such needs, in turn, are fueled by such changing demographics and lifestyles as older population, increased number of women acquired specially designed dining cars and equipped them with microwave ovens. In 1955, the Kaiser Hospitals in California began the first full-scale foodservice operation using microwave ovens. The first line of microwavable prepared foods was introduced by Morton Foods Div. of Continental Baking Co. Similarly, although the Wilson Menu Pak pouches were used in conjunction with special electric heating apparatus to reheat them, Morton first used high-density polyethylene trays with heat-sealed polyester film covers for its line of individual-portion and bulk-pack entrees, vegetables, and starches.

- In 1960, Armour Co. introduced its Continental Cuisine line of gourmet entrees, intended primarily for an à la carte menu in a restaurant. These entrees were packed into a dual-compartmented pouch, one with the entree, the other with side dishes.
- The retort pouch was pioneered by the U.S. Army Research and Development Laboratories, Continental Can Co., and Reynolds Metals Co. It played a key role in the early feeding of astronauts in space.

By now, it is evident that the foodservice segment of the food industry has played an important role in the development of various food technologies. Although the military sector has had perhaps the greatest influence on such developments, nonmilitary segments such as restaurants, health care, and transportation have also made significant contributions. Today, sales from the commercial and institutional segments of foodservice have completely overshadowed those from the military sector (Table 2).

Two important forces at work in the marketplace have contributed to this nonmilitary growth—one is the consumer’s exerting a “pull” effect, and the other is the foodservice industry’s exerting a “push” effect.
in the work force, single-parent/person households, two-income families, increasing nonwhite population (particularly Hispanic), popularity of ethnic foods, impact of diet on health and disease, indulgence (the "workout, pigout" syndrome), and "cocooning" (consumers spending more time at home).

As a result of these changing demographics, as well as economic, political, and social influences, the basic American lifestyle is undergoing a fundamental shift. Foremost in this shift are changes in eating patterns, food choices, and methods of food preparation. American consumers continue to exert their influence on the marketplace by requiring foods to have convenience, quality, freshness, variety, nutrition, and safety. These consumer demands in turn dictate the innovative application of food technologies for the development of unique products and processes.

Commensurate with the changing demographics and evolving lifestyles of the American consumer, the foodservice industry has also changed dramatically. Today, foodservice companies are seeking units or chains with concepts that differ from their own, and operators are altering menus, revising their recruiting and training programs, and revamping operational procedures. Foodservice firms are developing joint-venture programs and entering new markets, particularly in such areas as takeout and home-delivered foods (both of which are lucrative and rapidly expanding areas) and health-care foodservice, which, with the aging of the population, is one of the fastest-growing segments of noncommercial foodservice.

From a product and "health" point of view, we have witnessed the availability of fresh fruits and salads in quick-service, limited-menu restaurants; engineered foods such as surimi; "grazing" foods; "healthy" foods such as meals with low sodium, calorie, and cholesterol contents; takeout meals (for both away-from-home and in-home dining); and homedelivery of upscale complete meals for a busy but discriminating consumer.

**American consumers continue to exert their influence on the marketplace by requiring foods to have convenience, quality, freshness, variety, nutrition, and safety. These [demands] dictate the innovative application of food technologies. . . .**

With all these changes occurring and in response to these consumer pulls, the foodservice industry has once again turned to using existing, emerging, and/or new technologies for improving processes, developing new products, and increasing market share. Some examples of this technological push include developments in packaging, microwaves, extrusion, engineered foods, hydroponics, and biotechnology.

- **Packaging.** In food retailing, packaging serves two primary purposes: (1) as a medium for communicating information (i.e., ingredients, nutrient content, promotional material and other messages), and (2) as a functional preservative. However, in foodservice, functionality has always been the most important attribute, because the primary user of such packaged food is the operator, not the consuming public. With the current opportunities in takeaway and home delivery, the key to success will be quality meals (hot or cold) delivered in a package that is both functional and attractive. Packaging technology will play a major role in upgrading takeaway and delivery of foods.

  Two major packaging areas which have already had a significant impact on foodservice operators are the retort pouch and aseptic processing/packaging.

  **Retort Pouch.** Originally designed for feeding troops in the field, this technology soon became applicable to the mass feeding of the nonmilitary. Retort pouch technology is often viewed as the forerunner of aseptic processing/packaging.

  **Aseptic Processing/Packaging.** This technology involves the separate sterilization of both product and package at high-temperature/short-time conditions and their combination in a sterile environment. This technology has been used to process soups, gravies, sauces, beef stew, ravioli, meat spreads, and other products.

- **Microwaves.** The success of this technology for inhouse preparation of meals has led the food industry to develop a spate of ovenable/microwavable packaged foods. It is well known that microwave technology plays an important role in heating and cooking meals. However, in addition to these functions, it has now assumed a broader dimension, especially in foodservice. For example, microwaves are now being used for finish drying of potato chips and onion rings, resulting in better-quality products; cooking of potatoes and meat products such as bacon, sausages, and meat patties; proofing of donuts prior to yeast-leavening, resulting in lower fat absorption, increased shelf life, better "coatability," higher yields, and superior texture.

  In addition to these applications, microwave technology is being used in proofing of bread, pasteurization, precooking of poultry, fat rendering, puffing of snack foods (the best example being popcorn), and a myriad of other foodservice areas.

- **Extrusion.** Dating back to the early 1900s, extrusion is a process of forcing compounded ingredients through an orifice and molding products into desired shapes and sizes. It lends itself well to the production of fruit- or paste-filled snacks and hors d'oeuvres, laminated puff-pastry items with sweet or savory filled centers, and half-finished pellets which can be further processed at foodservice establishments.

- **Engineered Foods, sometimes called architectured or fabricated foods.** This technology involves the restructur-
The Foodservice Industry (continued)

ing of food components into new entities. Some of the early commercialized engineered foods were those made from soybean protein fiber spun into meat and poultry analogs, flavored and colored, and designed with controlled fat, protein, and carbohydrate contents.

In today's foodservice marketplace, engineered foods are becoming popular with both operators and consumers. For example, engineered breaded onion rings have (at the restaurant level) significantly reduced labor, cut down on waste, lowered caloric intake, improved quality and product uniformity, and considerably lowered cooking danger risks for employees, since there is no hot oil to contend with.

One of the most interesting engineered foods is one which originated in Japan—surimi. This technology involves deheading, deboning, washing, mincing, and forming fish into blocks, which are then frozen and stored until they can be processed into food products such as shrimp and crab analogs. Although this technology has been around for some time, only since the 1960s has the production and consumption of surimi steadily increased in popularity in the Western world. The acceptance of surimi is due to (1) increased consumption of fresh and frozen seafood over the past several years, with most of that growth due to foodservice; (2) product versatility, including simulated crab, shrimp, scallops, and a whole series of other

---

Table 2—Foodservice Industry Food and Drink Projected Sales and Purchases in 1989. From NRA (1988)

<table>
<thead>
<tr>
<th>Type of foodservice</th>
<th>Projected food and drink sales ($1,000)</th>
<th>Projected food and drink purchases ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1 Commercial Foodservice</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating Places</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restaurants, lunchrooms</td>
<td>74,384,088</td>
<td>25,290,590</td>
</tr>
<tr>
<td>Limited-menu restaurants, refreshment places</td>
<td>65,054,426</td>
<td>20,817,416</td>
</tr>
<tr>
<td>Commercial cafeterias</td>
<td>4,164,169</td>
<td>1,457,459</td>
</tr>
<tr>
<td>Social caterers</td>
<td>1,714,104</td>
<td>599,936</td>
</tr>
<tr>
<td>Ice cream, frozen-custard stands</td>
<td>1,800,057</td>
<td>511,198</td>
</tr>
<tr>
<td><strong>Total eating places</strong></td>
<td><strong>$147,116,844</strong></td>
<td><strong>$48,676,599</strong></td>
</tr>
<tr>
<td>Bars and taverns</td>
<td>10,331,537</td>
<td>481,656</td>
</tr>
<tr>
<td><strong>Total eating and drinking places</strong></td>
<td><strong>$157,448,381</strong></td>
<td><strong>$49,158,255</strong></td>
</tr>
<tr>
<td><strong>Food Contractors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing and industrial plants</td>
<td>3,657,046</td>
<td>1,609,100</td>
</tr>
<tr>
<td>Commercial and office buildings</td>
<td>1,269,326</td>
<td>558,503</td>
</tr>
<tr>
<td>Hospitals and nursing homes</td>
<td>1,561,159</td>
<td>575,880</td>
</tr>
<tr>
<td>Colleges and universities</td>
<td>2,433,277</td>
<td>754,510</td>
</tr>
<tr>
<td>Primary and secondary schools</td>
<td>1,120,044</td>
<td>384,348</td>
</tr>
<tr>
<td>In-transit foodservice (airlines)</td>
<td>1,041,590</td>
<td>499,901</td>
</tr>
<tr>
<td>Recreation and sports centers</td>
<td>1,734,669</td>
<td>556,829</td>
</tr>
<tr>
<td><strong>Total food contractors</strong></td>
<td><strong>12,817,111</strong></td>
<td><strong>4,939,071</strong></td>
</tr>
<tr>
<td><strong>Lodging places</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotel restaurants</td>
<td>11,750,432</td>
<td>3,618,676</td>
</tr>
<tr>
<td>Motor hotel restaurants</td>
<td>850,956</td>
<td>263,975</td>
</tr>
<tr>
<td>Motel restaurants</td>
<td>1,339,605</td>
<td>426,637</td>
</tr>
<tr>
<td><strong>Total lodging places</strong></td>
<td><strong>13,940,993</strong></td>
<td><strong>4,309,288</strong></td>
</tr>
<tr>
<td><strong>Other Commercial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail host restaurants</td>
<td>9,580,785</td>
<td>3,150,928</td>
</tr>
<tr>
<td>Recreation &amp; sports</td>
<td>2,425,474</td>
<td>783,525</td>
</tr>
<tr>
<td>Mobile caterers</td>
<td>806,184</td>
<td>249,111</td>
</tr>
<tr>
<td>Vending and nonstore retailers</td>
<td>5,015,693</td>
<td>1,525,322</td>
</tr>
<tr>
<td><strong>Total other commercial</strong></td>
<td><strong>—</strong></td>
<td><strong>5,708,886</strong></td>
</tr>
<tr>
<td><strong>Total Group 1</strong></td>
<td><strong>202,034,621</strong></td>
<td><strong>64,115,500</strong></td>
</tr>
</tbody>
</table>

*Data are given only for establishments with payroll

Expenditures by foodservice establishments for their food and drink supplies

Food purchases only

Includes drug and proprietary store restaurants, general-merchandise-store restaurants, variety-store restaurants, food-store restaurants, grocery-store restaurants, gasoline-service-station restaurants and miscellaneous retailers

Includes drive-in movies, bowling lanes, and recreation and sports centers

Includes sales of hot food, sandwiches, pastries, coffee, and other hot beverages
"grazing" foods which can be engineered with high protein, low fat, and low cholesterol contents and unique flavor and textural properties; and (3) high consumer awareness—67% for grocery buyers and 87% for restaurant customers.

- **Hydroponics.** This technology involves the growing of plants in a nutrient-enriched water solution (rather than in soil) under controlled conditions of lighting, temperature, and humidity. Hydroponic farming technology is closely related to controlled-atmosphere packaging and storage technology and is being applied to the growing of lettuce, spinach, herbs, spices, and other products. Although some hydroponically grown produce appears on supermarket shelves, most of it is destined for the restaurant business.

The stimulus for the increasing usage of this technology is at least twofold: (1) the focus on pesticide residues by the National Academy of Sciences, whose studies indicate concern about pesticide and other chemical residues on fresh produce and other foods, and (2) the consumer demands for "healthy" meals to go along with a healthy lifestyle.

Crops grown hydroponically are free from the dirt and grit that are common with field-grown produce, as well as herbicides, pesticides, and damage from pests and disease. These crops are of higher quality, are more consistent in

---

**Table 2 (continued)**

<table>
<thead>
<tr>
<th>Type of foodservice&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Projected food and drink sales&lt;sup&gt;b&lt;/sup&gt; ($1,000)</th>
<th>Projected food and drink purchases&lt;sup&gt;b&lt;/sup&gt; ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employee foodservice&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1,915,622</td>
<td>869,960</td>
</tr>
<tr>
<td>Public and parochial elementary and secondary schools</td>
<td>3,500,768</td>
<td>3,478,048</td>
</tr>
<tr>
<td>Colleges and universities</td>
<td>3,533,337</td>
<td>1,440,789</td>
</tr>
<tr>
<td>Transportation</td>
<td>1,317,523</td>
<td>669,618</td>
</tr>
<tr>
<td>Hospitals&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7,706,358</td>
<td>3,447,824</td>
</tr>
<tr>
<td>Nursing homes, homes for aged, blind, orphans, and mentally and physically handicapped&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3,555,162</td>
<td>2,184,149</td>
</tr>
<tr>
<td>Clubs, sporting and recreational camps</td>
<td>2,066,049</td>
<td>843,051</td>
</tr>
<tr>
<td>Community centers</td>
<td>572,904</td>
<td>676,015</td>
</tr>
<tr>
<td><strong>Total Group 2</strong></td>
<td>24,167,723</td>
<td>13,609,454</td>
</tr>
</tbody>
</table>

**Group 3**

**Military Foodservice<sup>f</sup>**

<table>
<thead>
<tr>
<th>Type of foodservice</th>
<th>Projected food and drink sales ($1,000)</th>
<th>Projected food and drink purchases ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defense personnel</td>
<td>2,189,961</td>
<td></td>
</tr>
<tr>
<td>Officers' and NCO clubs (&quot;Open Mess&quot;)</td>
<td>241,170</td>
<td></td>
</tr>
<tr>
<td>Foodservice—military exchanges</td>
<td>139,939</td>
<td></td>
</tr>
<tr>
<td><strong>Total Group 3</strong></td>
<td>2,570,800</td>
<td></td>
</tr>
</tbody>
</table>

**Grand Total**

85,319,715

---

<sup>a</sup>Includes industrial and commercial organizations, seagoing and inland-waterway vessels

<sup>b</sup>Includes voluntary and proprietary hospitals; long-term general, TB, mental hospitals; and sales or commercial equivalent to employees in state and local short-term hospitals and federal hospitals

<sup>c</sup>Sales (commercial equivalent) calculated for nursing homes and homes for the aged only. All others in this grouping make no charge for food served either in cash or in kind

<sup>e</sup>Continental U.S. only
The Foodservice Industry (continued)

size, are fresher, and have a longer shelf life than their counterparts grown in soil. But hydroponic crops do cost more. However, restaurants will pay higher prices because of the quality (especially when the produce is available in the winter months) and because of the significant reduction in labor involved in trimming and cleaning such crops before consumption.

- Biotechnology. This is perhaps one of the least understood of the technologies, but it is certainly not new. Alcoholic beverages, cheeses, and vinegar are but a few examples of products of this technology which date back to ancient times.

Modern agricultural biotechnology combines the blending of molecular genetics, plant breeding, tissue culture, and a whole series of life sciences to produce new foods or revise current ones with value-added functionality. Biotechnology can produce basic raw materials with specific functional properties to achieve better food formulation, processing, and stability after packaging.

One example of this technology is the production of potatoes from seed rather than tuber. True Potato Seed (TPS) is disease free, does not require special handling, does not rot, is free of waste, and costs less than its seed tuber counterpart. TPS provides for the development of potatoes with greater uniformity and higher quality. Equally important, these potatoes can be engineered to produce functional attributes desirable in frying and chopping.

- Other Technologies. Although the above list is by no means complete, it illustrates the critical role that food technologies have played and will continue to play in the foodservice industry. There are, of course, a whole series of other technologies which were omitted from this review—irradiation, agglomeration, supercritical fluid extraction, intermediate-moisture foods, microencapsulation, membrane technology, and a myriad of others—all of which are assuming greater importance in foodservice operations.

What's in Store for the Future

In speculating on the future of the foodservice industry, we view the industry as vibrant and continuing to grow at a healthy but moderate rate. Furthermore, we anticipate that foodservice will continue to command an increasing market share of the consumer's food dollar. However, the industry will also face mounting push-pull pressures in the marketplace:

- Serving the increasing number of older Americans with their needs for foods low in salt, fat, and cholesterol (three top consumer concerns) will be critical to menu development. Similarly, home delivery of quality, nutritious, and "safe" foods will become more important to the healthy elderly who may be less mobile.
- In takeout and home delivery of foods, there will be greater emphasis on upscale foods and beverages, and technological advances in food preparation and packaging

We view the industry as vibrant and continuing to grow at a healthy but moderate rate. . . . However, the industry will also face mounting "push–pull" pressures in the marketplace.

By remaining sensitive to the push–pull dynamics of the marketplace and by continuing to apply new technological and marketing . . . systems, the foodservice industry will become a dominant force in feeding the world population.

will improve the quality of both the service and the product. The pressures for biodegradable packaging materials will increase. Innovative application of microwave technology will play a key role in the growing markets for takeout and home-delivered meals. By the year 2000, automobile manufacturers may offer (at first as an option and then as standard equipment) mini-microwave units for automobiles, vans, and trucks.

- Regulatory involvement in labeling and assuring the quality and safety of foods in foodservice operations will accelerate. For example, confirmation of the safety of “sous-vide” technology (cooking and vacuum packaging) might persuade the Food and Drug Administration to allow use of this technology in individual foodservice establishments.
- The trend toward increasing use of fresh ingredients and foods will continue, increasing the opportunity for applying hydroponic systems and biotechnology to provide freshness. At one time, the Waldorf Astoria Hotel in New York City had its own hydroponic system to grow fresh herbs all year round.
- Supermarkets will emerge as aggressive competition to foodservice, particularly in the areas of takeout, home delivery, in-store bakeries, indoor and outdoor cafes and restaurants, and in-store delis (this industry “sizzler,” which has current sales of $6.6 billion annually, could double in size by 1991).
- Mergers and acquisitions, both domestic and foreign, will intensify competition in the foodservice industry. The European Economic Community and the highly competitive “Pacific Rim” market will further facilitate the internationalization of people’s lifestyles, tastes, products, travel, and interests. A world community once separated by physical and national boundaries is being transformed into massive central “markets” in which technology, foods, and cultures will be offered on a highly competitive basis.

We are confident that by remaining sensitive to the push-pull dynamics of the marketplace and by continuing to apply new technological and marketing (“techno-marketing”) systems, the foodservice industry will become a dominant force in feeding the world population.

References

—Edited by Neil H. Mermelstein, Senior Associate Editor

266 FOOD TECHNOLOGY—SEPTEMBER 1989
Food Toxicology and Safety Evaluation: Changing Perspectives and a Challenge for the Future

Richard L. Hall and Steve L. Taylor

Toxicology can be simply defined as the science of poisons. Food toxicology, then, is the study of toxins or poisons in food, whether they are natural or synthetic, or inherent, adventitious, or added. However, toxicology is much more than simply the science of poisons. It is a multidisciplinary field drawing from pharmacology, pharmacognosy, chemistry, biochemistry, and nutrition.

The food toxicologist is charged with gathering adequate information on the toxicity of foodborne chemicals and their mechanisms of action to make reasonable predictions of the hazards that these chemicals in food might present to the human population. The prediction of effects on humans from experimental results on other species is pivotal to toxicology. Thus, food toxicology might best be defined as the science that establishes the basis for judgments about the safety of foodborne chemicals.

It is worth noting that, in accordance with this definition, the Institute of Food Technologists has a Toxicology & Safety Evaluation Division rather than a "Food Toxicology Division."

The Genesis of Food Toxicology

The recognition of poisons in foods predates written history. Early man undoubtedly discovered the hard way that some native plants and animals contained acutely toxic chemicals and were therefore to be avoided.

In the past, foods also were occasionally used as a vehicle for intentional poisonings. Thus, the royal tasters might be considered the first food toxicologists, although they were more akin to experimental animals. Here, the poisons were placed, with evil intent, in otherwise safe foods. The recognition and avoidance of such tainted foods was not a simple task.

It is difficult to say with certainty when food toxicology became a distinct field of science. The early efforts noted above were unconnected and anecdotal observations that constituted a sort of forensic toxicology. The genesis of food toxicology occurred with the recognition that the chemicals found naturally in food, as well as those substances added to food, could have subtle as well as acutely toxic effects. Food toxicology as a distinct field of study, then, is not much older than IFT.

In the 18th century, food adulteration for profit was a widely recognized practice (Accum, 1820). Examples included the addition of chalk to bread and copper to pickles. Even though the adulterants were chosen with fraud, not safety in mind, only occasionally were they highly toxic. Although laws prohibiting food adulteration date back at least to the 13th century, increasing numbers of consumers lost control over their food supply as they moved from the farm to the city and farms became more specialized. This growing reliance on others to supply food fueled the concern over food adulteration.

In the United States, a turning point occurred in the early 1900s, when Harvey W. Wiley, Director of the Bureau of Chemistry in the U.S. Dept. of Agriculture, began to evaluate the safety of common food preservatives and ingredients with the help of his "poison squad," a group of male volunteers. The use of human subjects in these experiments attracted the public's attention and spurred the passage of the Food and Drugs Act of 1906, which defined food adulteration and made the distribution and sale of adulterated foods illegal. This act also prohibited the distribution and sale of adulterated drugs—fraudulent claims for many of the patent medicines available at the turn of the century and the presence of adulterants in those drugs were equally powerful arguments for this early legislation. Present concerns over the toxicity of food additives had their birth in the early efforts of the poison squad. These efforts marked the rudimentary beginnings of food toxicology and provided the impetus for the regulation of substances added to foods (Anderson, 1958; Wiley, 1930).

Thus, by the end of the Wiley era, we had moved gradually from an outrage over fraud, sometimes practiced with highly toxic substances, to a growing concern over the
more subtle toxic effects of common food preservatives and additives. We began to shift our focus from food adulteration to the safety of routinely used food ingredients. At the same time, concern over food additives began to displace concerns over the hazards posed by many naturally occurring substances in foods. The era of modern food toxicology had arrived in earnest.

Evolution of Toxicological Testing and Interpretation

Toxicological testing had its crudest beginnings in the work of the royal taster. From the royal taster to Wiley's poison squad, the use of humans for toxicological experimentation was a common practice, even though humans had obvious limitations as experimental animals. Despite these limitations, however, the use of animals to predict the toxicity of chemicals for humans did not become very common until the 1800s.

The genesis of food toxicology occurred with the recognition that the chemicals found naturally in food, as well as those substances added to food, could have subtle as well as acutely toxic effects.

At that time, a Spanish physician by the name of Mattieu Joseph Bonaventura Orfila, a professor at the University of Paris and attending physician to Louis XVIII of France, was one of the first to pioneer the use of animals for toxicological testing. Orfila was the first to correlate the chemical properties of poisons with their biological effects; he used...
Food Toxicology and Safety Evaluation (continued)

thousands of dogs in his experiments on the classical poisons of his day (Casarett and Bruce, 1980). Simultaneously, a number of physiologists were using poisons as experimental tools to unravel the mysteries of physiological function in animals. Later, in the 1900s, nutrition scientists studying vitamin deficiency diseases would again demonstrate the value of experimental animals in the study of human maladies. Today, nonhuman species are used almost exclusively in toxicological studies.

Thus, modern toxicology has drawn heavily from techniques used in physiology, pharmacology, and nutrition. In the early 1940s, more elaborate and systematic practices, described below, which we now call “classical” toxicology, began to be developed and used in testing foodborne chemicals in experimental animals. By then, the subject had gained further impetus from a major revision of our food and drug laws.

In 1937, a drug known as “Elixir of Sulfanilamide” was widely marketed in the U.S. as the first liquid form of a valuable new drug, sulfanilamide. The solvent was diethylene glycol, a rather toxic substance which contributed to the deaths of 105 persons nationwide (Ruprecht and Nelson, 1937). This tragic incident coalesced support that had been gathering for revision of the 1906 Act, and resulted in passage of the Federal Food, Drug, and Cosmetic Act of 1938. The new Act required the premarket review of all new drugs and drug ingredients, and it updated and tightened the definition of adulteration of food. The increasing emphasis on safety led to more use of animal testing.

As the use of animals in toxicological testing became more common, the techniques involved were constantly modified. To enhance the sensitivity of these animal bioassays, various changes were made, including the use of more animals per dose, higher doses, more thorough histopathological examinations, an increase in test duration, and the use of animals with defined genetic backgrounds. Many individuals were involved in the adaptation of animal bioassays to the safety evaluation of food ingredients. Bernard L. Oser, a nutritional biochemist by training, a past-president of IFT, and for many years the director of Food and Drug Research Laboratories, an independent toxicological testing laboratory, is particularly worthy of mention, in part because he recognized both the value and the limitations of animals as models for the human response (Oser, 1981a; b). Today, the use of animals to predict the toxicity of foodborne chemicals in humans is both common and indispensable, even though it remains an inexact science despite numerous improvements over the past 50 years.

Orfila was one of the first to point to the necessity of chemical analysis for legal proof of lethal intoxications, and he developed numerous methods for detecting poisons. The development in 1836 of a test for arsenic was particularly noteworthy because it removed from the unknown and undetectable one of the substances most widely used for murder. The ability of analytical chemists to detect ever lower levels of chemicals in foods has grown dramatically during the past 50 years. Today, analytical chemists can often detect substances in foods at nanogram and picogram levels.

Safety evaluation, the prediction of effects or noneffects on humans from experimental data obtained from animals, has evolved less far, but still considerably. Philippus Aureolus Paracelsus (1493-1541), was probably the father or godfather of toxicology and safety evaluation. The dose-response concept, the central axiom of toxicology, was first put forth by him (Paracelsus, 1564). In a frequently quoted dictum, he wrote: “Everything is poison. Only the dose makes a thing not a poison.” The concept that all substances are toxic at one dose, and safe at another, continues to escape many scientists and most consumers today. The Paracelsus dictum helped scientists realize that chemicals were not poisonous per se but that the dose of the chemical was critical in determining the degree of hazard. It took much longer for this concept to be incorporated into law. Today, we define toxicity as the inherent ability of a substance to cause harm. Hazard (or risk) is the probability, considering the dose and conditions of exposure, that harm will occur.

The 1938 Act prohibited the addition of a “poisonous or deleterious” substance to food. This was a qualitative, not a quantitative definition. Under the Act, substances were seen either as “safe” or “poisonous and deleterious” per se. The Act thus failed to recognize the importance of the dose-response concept and the Paracelsus dictum.

The 1938 Act also did not require safety evaluation prior to commercial use. In some instances, industrial or university laboratories conducted animal tests to demonstrate the safety of a substance. In many cases, in the absence of such testing, it was left to the Food and Drug Administration to establish, after commercial use had occurred, that a substance was unsafe. During the 1940s and '50s, FDA pushed ever higher the levels fed to test animals. Gradually, it became clear that Paracelsus was right—at some sufficiently high dose, everything is a poison. Fueled by increasing concern over the safety of additives, Congress passed the Food Additives Amendment of 1958 and the Color Additive Amendments of 1960 and thereby shifted the burden of proof of safety from FDA to industry. The new amendments effectively required pre clearance of food and color additives but, with the exception of the Delaney clause in each amendment, abandoned the poisonous per se concept in favor of safety “under conditions of intended use.” Under these amendments, the pace of animal testing, especially by industry, quickened markedly.

During all of this period, decisions were based on assessment of data from animal bioassays. The usual approach was to establish a “no-effect level” (NEL) or

The ability . . . to detect ever lower levels of chemicals in foods has grown dramatically during the past 50 years. Today, analytical chemists can often detect substances at nanogram and picogram levels.

We define toxicity as the inherent ability of a substance to cause harm. Hazard (or risk) is the probability, considering the dose and conditions of exposure, that harm will occur.
“no-observed-adverse-effect level” (NOAEL) by direct inspection of the dose–response relationship in animals. As with all safety evaluation, then and later, it was limited by the validity of the individual experiment and required extrapolation to humans.

Professor Rene Truhat pioneered the concept of the acceptable daily intake (ADI) in the 1930s and 40s. The ADI is obtained by dividing the NEL found in animal studies by a safety factor, usually 100. This 100-to-1 safety factor originally was rationalized by Arnold Lehman of FDA as including a factor of 10 for individual variation within the human species and a factor of 10 for variation between species, e.g., rats to humans. The inspection of data, gathered during the Elixir of Sulfanilamide incident, on variation among individuals in the lethal dose of diethylene glycol supported the first 10-fold safety factor. Later experiments with animals supported the 10-fold variation between species. Thus, the 100-fold safety factor was not unreasonable.

If the data are solid and the toxic effects of little concern, a smaller safety factor can be applied, leading to a larger ADI. If the data are less adequate, or the effects serious, a larger safety factor is appropriate, leading to a smaller ADI. The ADI should be a guideline, not a rigid limit. ADI has been used widely in other countries and by international organizations (WHO, 1987). It has not been explicitly adopted by FDA, but its logic lies behind many of the agency’s decisions. Within the past 30 years, more elaborate statistical approaches have been developed for “quantitative risk assessment,” as detailed below.

Factors Shaping Food Toxicology

Food toxicology has been shaped by the scientific, regulatory, and technological developments described above. But the field does not operate in a vacuum. It reflects, for good or ill, a host of social, political, economic, and technical influences. Among them are the consequences of the Industrial Revolution, including increased longevity, rising expectations, serious environmental damage, the complexity and remoteness of all technologies, including food technology, and the erosion of authority.

Public attitudes toward risk have changed; we have become far less tolerant of perceived risk. We no longer accept “fate”; we look for someone to blame. Our increasing longevity is largely due to the decreased risk of the serious infectious diseases, leaving us open to the consequences of old age and accompanying chronic diseases, of which the most feared is cancer. Some of this fear finds expression in laws and programs that seek to prevent cancer, even while we are still largely ignorant of many of its causes.

This increasing focus on cancer has had several impacts: (1) passage of the Delaney clause in the Food Additives Amendment and the Color Additive Amendments and (2) an increase in the emphasis on the chronic lifetime toxicological study or carcinogenicity test. The Delaney clause prohibits approval as a food additive of any substance “found to induce” cancer, thus imposing a zero tolerance for added carcinogens. In test animals as in humans, chemical carcinogenesis is a complex and extended process typically resulting from repeated long-term exposure. Thus, only long-term studies can uncover these risks. This has resulted in increased emphasis on chronic animal bioassays, with tumor development as the endpoint of principal concern. Scientists have consistently sought to push the sensitivity of such studies to the limit, to increase the probability of a response, by raising the dose as high as possible, and by using the most sensitive rodent strains. Unfortunately, as a result, these studies have often taken on the aspect of self-fulfilling expectations.

As noted above, along with changes in testing procedures and legal requirements, there has been enormous growth in sensitivity of analytical methods. We move constantly closer to being able to find a trace of anything in everything. The sensitivity and discrimination of our analytical methods far exceed the reach of our toxicological tests and our ability to interpret the results. For reasons discussed below, toxicological tests often produce results that raise more questions than they answer. Thus, we are aware of substances that may present threats we cannot measure, and we can measure effects in animals that we cannot interpret for humans. This disparity between the exquisite sensitivity of our analytical methods and the uncertainties that often attend animal bioassays serves to perpetuate our pervasive “cancerphobia.”

All of this has been supported—and frequently initiated—by a complex infrastructure of constituencies, with diverse, often self-serving, goals. They include some environmentalists and consulting firms, plaintiff’s attorneys and consumer activists, granting agencies and grantees, the genuinely worried, and those whose goal is major political change (Efron, 1984). The confluence of all of these has produced the toxicology of 1989.

Food Toxicology Today

The centerpiece of food toxicology today is the carcinogenicity study in two species, usually rats and mice, lasting for two years or more. It has often been conducted in a rote fashion, following standard protocols. Fortunately, there is now a trend toward individualized design that builds on preexisting knowledge of the particular compound under test. The test substance may be fed at only two levels, including the so-called maximum tolerated dose (MTD), or there may be three or more feeding levels. An undosed control group is included for comparison. The number of animals in each dosage group is often 50 of each sex. One of several routes of administration (e.g., ingestion, inhalation, skin absorption) may be used. If given orally, the test substance may be in the food or drinking water or given by gavage (stomach tube), usually in vegetable oil. An extensive histopathologic examination involving more than 30 organs and tissues, plus gross lesions and blood samples, is
Food Toxicology and Safety Evaluation (continued)

conducted at the end of the study. The level of the test substance in the diet or vehicle and the level of the substance or its metabolites in urine, feces, blood, and tissues are monitored. The costs are large and variable, ranging from $200,000 to $500,000 per species for each test substance.

While the test animal should be chosen, and the test designed, to most closely approximate human exposure and response to the substance, this is often not the case. Professional judgments differ, and compromises are common for many reasons, including cost, background data, and technical difficulties (Food Safety Council, 1980; NTP, 1984).

This superficial description begins to suggest the problems that attend the carcinogenicity study—the cost, the complexity, and the opportunities for error. The lack of sensitivity at low doses related to human exposure leads to the administration of high doses that often raise questions of relevance to human safety. The use of high doses also necessitates statistical extrapolation to lower and more relevant doses—an imprecise exercise at best. The large number of separate and independent histopathological examinations virtually guarantees a substantial incidence of "false-positive" results (Doull, 1981; Fears et al., 1977; Food Safety Council, 1980). The supporters of this test point to the high percentage—nearly 100%—of known human carcinogens that can be demonstrated to be carcinogenic in animals. The detractors point to an increasing number of cases of irrelevant and uninterpretable results.

Carcinogenicity studies have been extremely useful in confirming epidemiological results, and in interpreting or terminating the use of potentially dangerous substances, especially when the tests have been well designed and the results have been clear-cut. However, these carcinogenicity studies are complex and full of confounding factors. Nevertheless, the chronic study is often "the only game in town."

The emphasis on carcinogenicity testing has tended to reduce subchronic testing to a subordinate role, serving mostly to set the MTD for the chronic study. Subchronic studies of 28–90 days may remain the terminal study—or even be dispensed with entirely—only if all test results are clearly negative, the substance is metabolized by known and safe routes, and there are no other adverse data.

The acute toxicity test, the LD50, is disappearing as a useful measure of anything but the possible risks of accidental high-dose exposure. The results do not correlate with those from longer-term, repeated exposures.

The most significant recent development has been the increasing use of toxicokinetics, an assessment of the rates, routes, and products of absorption, distribution, metabolism, and excretion. This knowledge is useful in setting more relevant doses in feeding tests and interpreting the results. It illuminates the relationships between chemical structure and physiological activity. When, as often happens, a metabolite, rather than the test substance itself, is the ultimate cause of harm, such information carries us toward an understanding of mechanisms of action. It permits, for example, making the distinction between primary and secondary carcinogens. It makes possible much more realistic risk estimates. The evolution and application of these techniques, as in the case of methylene chloride, is one of the most constructive results of our more sensitive analytical methods (IFT, 1988; Serota et al., 1986).

Together, all of these developments have resulted in an increased emphasis on priorities. We can afford neither the costs nor the risks of running all tests on all substances. Increasingly, toxicologists and regulators agree that to do so would waste scarce resources on trivial or nonexistent risks. Information from past toxicological testing, and on structure/activity relationships derived in large part from increasing knowledge of metabolism, has been the basis for prioritization (Anonymous, 1982; Cramer et al., 1978).

Another result of these developments is the search for alternatives to the chronic study. Chief among these have been the short-term tests (STTs), which use microorganisms, cell cultures, and certain cells exposed in vivo as model systems for whole animals and, by implication, for humans. STTs, such as the Ames test with modified salmonellae, are based on evidence that most carcinogens act by modifying the genetic material of cells. The underlying assumption is that substances that show genotoxic effects in single cells may also exhibit mutagenic or carcinogenic effects in animals or man.

Initially, correlations of the results of STTs with those from carcinogenicity tests were highly favorable. This appears, however, to have been due to the skewed selection of test substances and testing methods in those comparisons. Substantial doubt now exists that the STTs, in their present state, have useful predictive value (Tennant et al., 1987).

In spite of these costs, complexities, and uncertainties, there remains the need to arrive at informed regulatory decisions. There is every evidence that the use of the ADI to define safe use has protected the public health very well. But it suffers from the apparent disadvantage that it does not purport to tell how safe is "acceptable," i.e., it does not try to estimate the risks.

The ability of analytical chemistry to detect trace impurities has made the zero tolerance for carcinogens imposed by the Delaney clause impossible to implement. To avoid "paralysis by analysis," it has become common practice to define an exposure, and an associated risk level, so low that it may reasonably be regarded as "negligible," "insignificant," or "de minimis." Doing this requires extrapolation from the data on tumor incidence at high dose levels in experimental animals to predict the risk of cancer in humans exposed to much lower doses of the chemical.

A variety of statistical methods are employed in risk assessment. They differ in their assumptions about the shape of the dose-response relationship in humans exposed to very low doses, several orders of magnitude below any dose that can realistically be included in the animal bioassay. One must then generalize from the test animal, across species, to humans. These efforts to cope with the absolutism of the Delaney clause have laid on toxicology the need for much greater emphasis on statistics, predictions, and extrapolations. These techniques are a great convenience to those who need or trust them, but to the more skeptical they represent no more than ingenious mathematics to cover missing biological data.

The foregoing discussion thinly covers the major emphasis of toxicology today. Food toxicology in 1989 is still an inexact science, even though it has matured greatly over the past 50 years. Emerging topics, difficult now to assess,
Food Toxicology and Safety Evaluation (continued)

remain. These include teratogenesis (the evaluation of reproductive anomalies), neurobehavioral effects, immunotoxicology, and mutagenesis.

The Problems of Today

The major challenge to toxicology in 1989 is to improve the assurance that the predictions about human safety are relevant. Such assurance is easy for any toxicological endpoint if:
- The test results are clear-cut.
- The animal model is clearly relevant at doses reasonably related to human exposure.
- All the data are generally adequate and supportive.
- However, discomfort and doubt increase if:
- The effects are marginal or of questionable significance.
- The relevance of the model or the test is less than clear. For example, humans have no forestomach; rats do. Also, what meaning do results from inhalation studies have if our concern is solely with ingestion?
- Doses are absurd or irrelevant. Doses in one National Toxicology Program carcinogenicity bioassay were fed at 32,000,000 and 64,000,000 times human exposure. In some cases, the MTD has exceeded the metabolic capacities of the test animal, raising considerable concern about the relevancy of the findings.
- There is no support from data on the other sex, another species, epidemiological findings, structure/activity relationships, or STTs.

All of these problems come most frequently and sharply into focus in the carcinogenicity test because:
- These tests are often an example of technology pushed far beyond its base of understanding in basic science.
- Public concern expects a precision of results that biology cannot now, or ever, deliver.
- Except for most lung cancers and certain rarer cancers of industrial origin, we do not know the causes of most cancers.
- Analytical chemistry has made us aware of possible threats we cannot directly demonstrate toxicologically.
- Toxicology demonstrates potential risks we cannot evaluate in human terms.
- Available methods of risk analysis used as decision aids involve a succession of mostly conservative assumptions, and these produce unrealistically high estimates of risk.

All of these factors serve to reinforce concerns in an already risk-aversive and mistrustful public. And beyond these are the personal agendas of many of the participants.

In recent years, toxicology has had to attempt to cope with selective risks—those encountered by only a small percentage of the exposed population. Allergies to food components, natural and artificial, and intolerances to substances such as gluten, tartrazine, and sulfites are examples. Toxicology ignored these in the past. It could not deal with them because there were no satisfactory animal models. The lack of models persists, but the freedom to ignore these hazards does not (Taylor, 1985).

Another problem we can only note and not explore is the issue of what are "acceptable" risks. These depend on whether they are perceived as voluntary or involuntary, vital or nonvital, familiar or unfamiliar, and large or small (Lowrance, 1976; Starr, 1969).

Current efforts to cope with these problems involve the following:
- Priorities for the allocation of resources toward solutions that can result in the greatest public health protection.
- Improvements in testing methods. These include (1) emphasis on toxicokinetics, and, based on these data, tests designed specifically for the particular test substance; and (2) efforts to make risk assessment more realistic.

Faced with overstated, or unevaluatable risks, it seems logical to look for benchmarks of acceptable risk, such as those naturally present in the food supply. Some of the greatest hazards in the food supply may be of natural rather than human origin. Efforts to use such benchmarks have only begun, but they suggest that we should work toward making risk assessment only relative, not absolute (Hall et al.; Ames and Gold, 1989; Scheuplein, 1989).

The Challenges of the Future

Assessing the challenges of the future involves, even more than the past or present, the biases of the observer. What follows requires not merely optimism but "leaps of faith."

It seems clear that the developing science and the creativity of food technologists will continue to provide wholly new foods, such as those from cell or tissue culture; major new ingredients such as the sucrose esters, unconventional sugars, or modified fats; major new processes such as food irradiation and extrusion cooking; and the products of biotechnology.

Conventional toxicology deals very poorly with these challenges, for the same reasons that it has had difficulty in the past with traditional foods and food processes: We cannot feed high enough levels of foods or major food components in test animals to reach an acceptable safety factor. Such diets may be nutritionally inappropriate or inadequate. All foods contain minor, and often unavoidable, toxic components that we would never permit for intentional addition. Specifications are usually impossible, so knowledge of what one is testing is incomplete. Toxic effects from one component may precede, overshadow, or preclude those from another.

In coping with all of this, we may use, rather than statistics, the growing power of analytical chemistry to understand the composition, metabolism, and toxicokinetics of these new entities at realistic feeding levels and to compare them with their traditional counterparts. We may then use the traditional foods and their risks as benchmarks for acceptable risk.

For any food component, major or minor, we may then be able to identify its key active metabolites and measure their concentrations in target tissues. For risk-assessment purposes, this will be far more relevant than the current practice of using the amount of the test substance admin-

The major challenge to toxicology in 1989 is to improve the assurance that the predictions about human safety are relevant.
istered to the animal. Through measuring concentrations associated with damage at the relevant sites, we may be able to develop "biochemical markers" as predictors of damage to come (Saffioti, 1977).

All of this, one may reasonably expect, will permit studies at lower and more realistic doses. When combined with comparative metabolic studies, including those in humans, results will be more relevant, and improved estimates of risk will be attainable. Even now, it is appropriate to ask how many examples of metabolic thresholds we will require before the linear model for risk assessment is no longer accepted as an article of faith.

In spite of their current lack of reliability and interpretability, a future remains for the STTs. They suffer now, not because there is no connection between genetic damage and carcinogenesis, but because of the artificiality of the model system and the complexity of the whole animal. Other processes and events in humans and in test animals overwhelm and obscure what connections there may be between genetic damage and carcinogenesis. Increased knowledge of mechanisms of tumor formation and progression may well help design and select STTs that do have relevance and interpretability, at least for those carcinogens that act by genotoxic mechanisms.

Evidence from epidemiology suggests that as our knowledge of the actual causes and mechanisms of human cancers increases, this will deflect attention away from our present concerns with chemical carcinogenesis from added and adventitious chemicals toward other factors, including lifestyle, disease, natural toxicants, promoters and inhibitors, genetic background, and environmental factors other than chemical exposure.

Teratogenesis will continue to be an important field of activity and interest, particularly for wholly new chemical entities. Major further developments could stem from increases in our currently limited knowledge on the mechanisms of growth and differentiation in the embryo. The increasing knowledge of metabolic mechanisms and molecular biology may open up ways to deal with the now refractory problems of allergenicity and intolerance.

Behavioral toxicology clearly exists as a field of study; it is as near as the neighborhood bar. Unfortunately, it is also the softest science of all the emerging fields. The utility of animal models is unclear. The lack of physical endpoints leaves the results more uncertain than in the more conventional areas of toxicology.

Immunotoxicology will doubtlessly receive more attention, driven partly by the implications of the usefulness of immunosuppressive drugs, and partly by our increasing recognition of the importance of our immunological defenses and the variety of factors, including nutritional ones, that can compromise them.

Perhaps most hopeful of all, as a better knowledge base develops, we may have the means to seek improved public understanding of relative risks, and of steps that enhance our control of those risks. This may encourage greater willingness to assume appropriate individual responsibility for risk reduction in our own lives. Herein lies our greatest hope and our greatest challenge. It can properly engage the best efforts of all of us.
References
World Health Org., Geneva.

—Edited by Neil H. Mermelstein, Senior Associate Editor

MAKE THE SAFEST, MOST EFFECTIVE USE OF FOOD ADDITIVES

Yours to examine FREE!

New!
FOOD ADDITIVES HANDBOOK

By Richard J. Lewis, Sr.,IFT

$64.95, 600 pages, ISBN 0-442-20508-2

Eliminate time-consuming research and assure safe storage and usage with this valuable guide to more than 1300 food additives. Separate, alphabetically-arranged entries give you ready access to a wide range of data on direct and indirect additives, packaging materials, pesticides, selected animal drugs, and much more.

Detailed listings for each substance and two sets of cross indexes allow you to quickly recognize important properties, hazards, and regulations. With Food Additives Handbook you'll get such practical information as • chemical properties (including form, color, odor, boiling and melting points, and explosive limits) • usage and handling requirements of U.S. federal agencies • recent findings on toxicological and carcinogenic agents • CAS and DOT numbers • synonyms (including generic and foreign names and codes) • and unintentional additives such as pesticides. Coverage also includes the latest OSHA recommendations for exposure levels and CODEX bibliographic citations.

FREE EXAMINATION RESERVATION FORM

For information circle 224
The Institute of Food Technologists was formed in 1938, one year after enactment of the Federal Food, Drug, and Cosmetic Act of 1938 [52 Stat. 1040 (1938); 21 U.S.C. 301 et seq.] and just as that statute was initially being implemented by the Food and Drug Administration. [The FD&C Act became effective one year following its enactment on June 25, 1938, and portions of it were postponed for an additional year in 53 Stat. 853 (1939).] Thus, the development of food law pursuant to the FD&C Act, under the leadership of FDA, has directly paralleled the development of food science, under the leadership of IFT. As food technology has evolved during the past 50 years, FDA has sought to keep pace through changes in the legal requirements imposed upon the food and agriculture industry. 

Development of Laws Regulating Food

Throughout history, from earliest recorded times, civilized societies have instituted governmental controls over the integrity of the food supply (Hutt and Hutt, 1984). English laws regulating food were brought to America with our early settlers, enacted as colonial laws, and retained as state laws following the Revolution. Spurred on by well-publicized reports of widespread food adulteration in the mid-1800s, virtually every state enacted laws regulating the food supply before 1900. At the same time, Congress enacted federal laws regulating the import and export of food products. But Congress stopped short of regulating food law pursuant to the FD&C Act, under the leadership of FDA, has directly paralleled the development of food science, under the leadership of IFT. As food technology has evolved during the past 50 years, FDA has sought to keep pace through changes in the legal requirements imposed upon the food and agriculture industry.

Structure and Organization of FDA

In 1846, Professor Lewis C. Beck, M.D., of Rutgers College published the first American treatise on adulteration of food and drugs (Beck, 1846). Two years later, at the request of Patent Commissioner Henry L. Ellsworth, Congress authorized the Commissioner to conduct chemical analyses of the American food supply [9 Stat. 284, 285 (1848)], and Beck was recruited to become the first chemist of the Patent Office (Caffrey, 1916; Weber, 1928).

When the U.S. Dept. of Agriculture was created by Congress in 1862, the Patent Office chemical laboratory was transferred to the Division of Chemistry in the new department. The Division of Chemistry became the Bureau of Chemistry in 1901; the Food, Drug, and Insecticide Administration in 1927; and the Food and Drug Administration in 1931. FDA was transferred from USDA to the Federal Security Agency in 1940 and to the U.S. Dept. of Health, Education, and Welfare in 1953, which became the U.S. Dept. of Health and Human Services in 1979. It was not until 1988 that Congress established FDA by statute [102 Stat. 3048, 3121 (1988)].

Food regulation within FDA has always been split between the headquarters, located in Washington, D.C., and the field offices, located throughout the country. Throughout history, from earliest recorded times, civilized societies have instituted governmental controls over the integrity of the food supply.

Central policy, including the development of regulations, has been established at headquarters. Inspection and enforcement activities, often including laboratory analyses, have been handled in the field, under the general direction of headquarters. At the time the FD&C Act was enacted, the policy work at headquarters was conducted by a Food Division. The field was divided into three districts, which in turn directed the activities of 16 field stations. In 1948, the three districts were dismantled, half their people were transferred to Washington to centralize policy and direction, and the 16 field stations became district offices. At headquarters, compliance activities were centralized in a new Bureau of Enforcement in 1956, which was split into a Bureau of Regulatory Compliance and a Bureau of Education and Voluntary Compliance in 1963 and then recombined as the Bureau of Compliance in 1968. Food policy was similarly delegated to a Bureau of Biological and Physical Science in 1956, which was split into the Bureau of Scientific Research and the Bureau of Scientific Standards and Evaluation in 1963 and then recombined as the Bureau of Science in 1966.

In 1970, the current agency structure was set in place. A
Bureau of Foods was created (now renamed the Center for Food Safety and Applied Nutrition), with responsibility for all policy, science, and enforcement relating to human food. A related Bureau of Veterinary Medicine (now the Center for Veterinary Medicine) has responsibility for animal feed and drugs, including their impact upon human food. This organizational structure has allowed FDA to focus upon food issues in a comprehensive and detailed way, and thus has proved to be the most effective means for the agency to conduct its work.

The FDA Budget
In 1939, FDA had a total budget of $2.2 million for all of its responsibilities, including enforcement of the Insecticide Act [52 Stat. 710, 742-743 (1938)]. Of this budget, about 70% was devoted to food matters. At the time of the first report of the Citizens Advisory Committee (1955), FDA's budget was $5.1 million, and FDA's staff consisted of about 1,015 people, of whom more than half were devoted to food matters. By the time of the second report of the Citizens Advisory Committee (1962), the total budget had been increased to $23.1 million and the number of employees to 3,012, of whom more than half were again devoted to food matters. As a result of new statutory authority, the growth and increased complexity of the regulated industry, and major investigations and reports on FDA since then (Hutt, 1984), the FDA budget and personnel have increased dramatically (Table 1).

During this same time, the American population and the food and agriculture industry also increased dramatically (Table 2; Bureau of the census, 1960).

FDA Enforcement Action
In 1939, FDA relied primarily upon direct formal action in the courts to enforce the FD&C Act. These court enforcement actions involved seizure of the product and criminal prosecution of individuals and companies responsible for violations of the law (the two court actions authorized by the 1906 Act). Later, injunctions (authorized under the FD&C Act) against violation of the law were also used. In addition to these formal court enforcement actions, the agency inspected and detained imported food and sampled thousands of domestic products.

Under the 1906 Act, FDA had promulgated relatively few regulations, and they had remained in place for decades without significant change (Hutt, 1981). Following enactment of the FD&C Act, FDA began to issue additional regulations, particularly to codify the requirements for food labeling and food standards.

As FDA increased its emphasis on the promulgation of regulations to control the food supply, its use of formal court enforcement actions was reduced accordingly. After 25 years of implementing the FD&C Act, for example, the FDA enforcement statistics relating to food had changed substantially, as shown in Table 3.

By the early 1970s, FDA's method of enforcement had
Development and Growth (continued)
changed dramatically, for three interrelated reasons. First, the issues faced by FDA were increasingly more complex and judgmental, and no longer could be characterized as obvious or direct violations of the FD&C Act. Second, for that reason, FDA increasingly relied upon promulgation of detailed regulations and lengthy preambles to impose new requirements under the FD&C Act, rather than relying upon direct enforcement action in the courts under the terms of the statute itself. And third, the resulting reduction in ambiguity and uncertainty allowed the agency to rely much more heavily on informal enforcement methods which were far less expensive and more efficient (Hutt, 1973). Within a few years, informal enforcement actions virtually displaced formal court enforcement actions. This is reflected in the 1987 enforcement statistics (shown in Table 3), which include all FDA activity, not just food.

Food Research
The original mission of the predecessor agencies to FDA was research. Only after enactment of the 1906 Act did FDA turn its attention to enforcement as well. As a result, FDA has had a long and distinguished history in food research. For the past 50 years, that research activity has been conducted both internally and through external grants and contracts. Virtually all of this research has been directed at regulatory issues, to help FDA implement its statutory responsibilities more completely and more efficiently. The results of this research can be found in the FDA Annual Reports, the Quarterly Reports of Activities, Federal Register notices, scientific papers published by agency employees, the records of daily enforcement activities, and other related documents.

Since the reorganization of 1970, when the Bureau of Foods was created, most of the FDA research relating to food has been conducted within, or arranged by, that bureau. At the same time that the Bureau of Foods was created, FDA acquired the National Center for Toxicological Research (NCTR), located in Jefferson, Ark. During the past 18 years, NCTR has contributed significantly to research on food safety. The Bureau of Veterinary Medicine has also conducted research on the impact of animal feed and drugs on human food.

Under the FD&C Act, FDA has responsibility for preventing any form of adulteration or misbranding of food. The evolution of FDA's specific substantive activities in implementing these statutory provisions is discussed by Hutt (1989) and Middlekauff (1989). The research program of the agency has been closely related to these statutory mandates.

Fundamental to all FDA food enforcement activities is the ability to detect and quantify the presence of substances in the food supply.

<table>
<thead>
<tr>
<th>Estimated 1988</th>
<th>Proposed 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of employees</td>
</tr>
<tr>
<td>Human food</td>
<td>2,088</td>
</tr>
<tr>
<td>Animal food and drugs</td>
<td>441</td>
</tr>
<tr>
<td>National Center for Toxicological Research</td>
<td>232</td>
</tr>
<tr>
<td>Administration</td>
<td>390</td>
</tr>
<tr>
<td>All FDA</td>
<td>7,073</td>
</tr>
</tbody>
</table>

Table 1—FDA Personnel and Budget, 1988 and 1989. From FDA (1988b)

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (million)</th>
<th>Total personal food expenditures ($ million)</th>
<th>Total personal expenditures ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>131.0</td>
<td>19,164</td>
<td>67,578</td>
</tr>
<tr>
<td>1953</td>
<td>159.6</td>
<td>65,241</td>
<td>238,025</td>
</tr>
<tr>
<td>1962</td>
<td>186.5</td>
<td>84,220</td>
<td>355,360</td>
</tr>
<tr>
<td>1987</td>
<td>244.8</td>
<td>514,500</td>
<td>2,966,000</td>
</tr>
</tbody>
</table>

Table 2—Population and Expenditures, 1939–87. From Bureau of the Census (1960)
When it became clear that trace levels of carcinogens could be found throughout the food supply, FDA pioneered the use of quantitative risk assessment to assure continued public safety.
Development and Growth (continued)

An Enduring Partnership with Industry

Fifty years ago, when IFT was founded, food technology was in its infancy. But even then, FDA had a long tradition, and several decades of actual experience, in regulating the food supply.

Since 1939, FDA has become a much larger, stronger, and far more sophisticated scientific regulatory agency. Even with today's budget constraints, it has the expertise and the capacity to assure the American public of a safe, nutritious, and accurately labeled food supply. As food technology has become more complex, therefore, FDA has in fact been able to keep pace. Thus, the U.S. food and agriculture industry has had the benefit of a strong and enduring partnership with FDA, in making available the numerous benefits of modern food technology while preserving the integrity of the food supply itself.

References


Hutt, P.B. 1985b. Use of quantitative risk assessment in regulatory decisionmaking under federal health and safety statutes.

50 Years of Progress (continued from page 107)


Based on a paper presented during the plenary session, "The Progress of Food Science and Technology Over the Past 50 Years," at the 50th Anniversary Annual Meeting of the Institute of Food Technologists, Chicago, Ill., June 25-29, 1989.

—Edited by Neil H. Mermelstein, Senior Associate Editor
Regulating the Misbranding of Food

Peter Barton Hutt

When Congress enacted the Federal Food, Drug, and Cosmetic Act (FD&C Act) in 1938, it included, for the first time, a number of new provisions governing the misbranding of food that had not been part of the Food and Drugs Act of 1906. It strengthened the prohibition against debasement of food, by authorizing the Food and Drug Administration to establish mandatory food standards. It required the affirmative labeling of food with mandatory information specified in the statute, authorized FDA to require additional label information for special dietary foods, and required that food labeling affirmatively reveal all facts material in the light of any other representations made for the product. It continued the former prohibition of false or misleading statements in food labeling. It also prohibited slack fill and deceptive packaging.

In implementing these provisions, FDA has necessarily both relied on and responded to developments in the food and agriculture industry to guide its activities. Thus, the history of FDA regulation of food misbranding during the past 50 years directly mirrors the development of food science and technology during this time.

The statutory provisions enacted by Congress in 1938 to regulate food misbranding have remained virtually unchanged. Although Congress has considered numerous bills to revise and extend the food misbranding provisions of the FD&C Act (Hutt, 1979), none has been enacted. This history therefore reflects evolving administrative policy implemented by FDA, not statutory changes adopted by Congress.

This history is split into two eras, divided by the White House Conference on Food, Nutrition, and Health held in December 1969. The Conference report (White House Conference, 1970) and the new FDA leadership that was committed to implementation of the regulatory policy recommended in that report profoundly changed FDA’s approach to food regulation and permitted the full use of modern food technology.

1939–69

Following enactment of the FD&C Act in 1938, FDA relied primarily upon five statutory provisions to regulate food misbranding: (1) the mandatory information required by the statute to appear on all food labels, (2) mandatory standards of identity for food products, (3) the labeling of imitation food, (4) nutrition information for special dietary food, and (5) the prohibition of any false or misleading claims.

1. Mandatory Food Labeling. Under Section 403 of the FD&C Act, every food label must bear, at the very minimum, the following four categories of information: the name of the food; a statement of the ingredients; the net quantity of contents; and the name and address of the manufacturer or distributor. Under the 1906 Act, as it was originally enacted, none of this information was required. The Gould Amendment of 1913 for the first time required that the net quantity of contents be labeled on food packages [37 Stat. 732 (1913)]. Thus, these provisions of the FD&C Act represented a major new requirement for all food packaging, and forever changed the very nature of food labeling.

Within months after the FD&C Act was enacted, FDA had promulgated regulations to implement these requirements [3 Fed. Reg. 3161, Dec. 28, 1938]. Although these regulations have subsequently been amended many times to refine minor details, their basic thrust has never been changed.

The White House Conference . . . report [published in 1970] and the new FDA leadership that was committed to implementation of the regulatory policy recommended in that report profoundly changed FDA’s approach to food regulation and permitted the full use of modern food technology.

2. Standards of Identity for Food. Ancient botanists, beginning with Theophrastus (370–285 B.C.), established “standards” by describing the available food supply and warning against its adulteration with other substances (Hutt and Hutt, 1984). Standards of identity for bread were established in the Roman Empire and in medieval England, to assure the integrity of the food supply. The same approach has been pursued to the present.

Even before enactment of the 1906 Act, FDA had established some 200 informal food standards (USDA, 1903; 1904; 1906a; b). Although Congress declined to include legal authority for mandatory food standards in the 1906 Act, FDA continued with this work until the FD&C Act was enacted in 1938 (Hutt and Hutt, 1984, p. 60).

Section 401 of the FD&C Act authorized FDA to promulgate definitions and standards of identity for any food product in order to “promote honesty and fair dealing in the interest of consumers.” Because of its long interest in
food standards, FDA promptly moved to implement this new authority. Although the FDA food standards activities were interrupted by World War II, they continued as a high agency priority for the two decades following the war. By 1970, it was estimated that half of the American food supply was subject to an FDA food standard.

When these early food standards were adopted, modern food technology was just beginning to flourish. Some functional food ingredients (e.g., preservatives, emulsifiers, thickeners, and so forth) were in use, but many staple foods remained quite simple and had not yet undergone the transformation that later occurred. Moreover, at this time FDA had no independent statutory authority to require premaket testing and approval of new food additives for safety. Accordingly, FDA adopted the policy of establishing “recipe” standards of identity, under which every permitted ingredient was specifically listed in the standard. Under this policy, no new ingredient could be used until the standard was amended to include it. Accordingly, all progress in food technology for standardized foods depended upon amendment of the applicable food standards.

With enactment of the Food Additives Amendment of 1958 [72 Stat. 1784 (1958)] and the Color Additive Amendments of 1960 [74 Stat. 397 (1960)], and the rapid develop-
Regulating the Misbranding of Food (continued)

ment of food technology, use of recipe standards was no longer warranted. FDA initially experimented with a new, broader form of standard, which permitted any "safe and suitable" functional ingredient, in the 1960s, but did not move to broaden all of the existing standards.

One particular aspect of food standards, not specifically mentioned in the statute, became a principal focus of this activity. Developing knowledge about essential vitamins and minerals during the 1930s led the American Medical Association’s Council on Food and Nutrition to adopt a policy that food fortification should be reserved for exceptional cases where there is convincing evidence of a need for the vitamin or mineral and where the food to be fortified is a suitable carrier (AMA, 1933; 1936; 1939).


3. Imitation Food. The 1906 Act had prohibited imitation food. Section 403(c) of the FD&C Act provided, however, that any imitation food must be labeled as an imitation.

FDA initially sought to apply this statutory provision to control the development of new substitute food products. It argued that any imitation of a standardized product was inherently illegal, but the Supreme Court overruled the agency on this point in 1951 [62 Cases of Jam v. United States, 340 U.S. 593 (1951)]. When a substitute ice cream was made from soybeans and marketed as “Chil-Zert,” FDA brought a successful legal action to require that it be labeled as an imitation ice cream [United States v. 651 Cases, More or Less, of Chocolate Chil-Zert, 114 F. Supp. 430 (N.D.N.Y. 1953)]. This was, however, the high point of FDA’s use of the imitation provision to inhibit the marketing of new food products. As food technology progressed, and more substitute products were marketed, the agency did not institute legal action to prevent their sale.

Nonetheless, FDA did adhere tenaciously to the position that the name of a standardized food could not be used as part of the name of a nonstandardized substitute product. The Supreme Court had ruled in 1943 that, once FDA had established a standard of identity, the statutory prohibition not be evaded by adding nonpermitted ingredients and revising the name of the food to reflect that change [Federal Security Administrator v. Quaker Oats Co., 318 U.S. 218 (1943)]. Thus, FDA insisted that a reduced-calorie or reduced-fat French dressing be labeled as an “imitation French dressing,” whereas any reduced-fat or reduced-calorie Russian or Italian dressing could be labeled as such, because the only salad dressing subject to a standard of identity was French dressing.

Moreover, FDA took no administrative action to clarify its position on the imitation provision. Several states therefore brought action against new substitute food products under comparable provisions in their state laws (Merrill and Hutt, 1980). The resulting confusion led to widespread apprehension about the status of new products under the law (Cody, 1970).

4. Special Dietary Food Labeling. Under Section 403(j) of the FD&C Act, FDA was authorized to promulgate regulations to require label information concerning the vitamin, mineral, and other dietary properties of food represented for special dietary uses. In November 1941, following a public hearing, FDA promulgated regulations governing vitamin-mineral supplements, fortified food products, and such other special dietary foods as infant food, hypoallergenic food, and food used in weight control [6 Fed. Reg. 5921, Nov. 22, 1941].

Because these were labeling requirements and imposed no limit upon other claims or permissible formulations, the types of special dietary products marketed, and the claims made for them, proliferated. In spite of numerous court actions and educational approaches, FDA could not bring these products under control. Indeed, one court case concluded that nutrient fortification of sugar could not be banned by FDA [United States v. 119 Cases . . . New Dextra Brand Fortified Cane Sugar, 231 F. Supp. 551 (S.D. Fla. 1963), aff’d, 334 F.2d 238 (5th Cir. 1964)].

As a result, FDA concluded that the only reasonable approach to this matter would be through revision of the 1941 regulations. As part of the proposed regulations to restrict food fortification already discussed above [27 Fed. Reg. 5815, June 20, 1962; 31 Fed. Reg. 8521 June 18, 1966; 31 Fed. Reg. 9215, July 6, 1966; 31 Fed. Reg. 15730, Dec. 14, 1966; 32 Fed. Reg. 5736, April 8, 1967], FDA proposed to limit the number of permitted formulations of dietary supplements of vitamins and minerals and to ban common labeling claims for these products that the agency regarded as false or misleading. These proposals were also part of the formal public hearing conducted during 1968 and 1969.

5. Prohibition of False or Misleading Claims. Like the 1906 Act, Section 403(a) of the FD&C Act prohibited any false or misleading statement in food labeling. Most fraudulent or outrageous food claims had long since disappeared as a result of FDA regulatory action taken under the 1906 Act. With the advent of food fortification and vitamin-mineral supplements, and the gradual unfolding of scientific evidence about the relationship of diet and health, new regulatory problems emerged.

FDA regulation of labeling claims relating to food fortification and vitamin-mineral supplements has already been discussed above. Ultimately, the agency sought during the 1960s to control these problems through promul-

FDA adopted new regulations governing nutrition labeling for all food. . . . This has resulted in the now-familiar nutrition labeling format estimated to be used on more than half of the United States food supply.

290 FOOD TECHNOLOGY—SEPTEMBER 1989
Regulating the Misbranding of Food (continued)

gation of restrictive new regulations.

The emergence of new scientific information about the relationship of diet and health, however, created entirely different concerns. FDA readily permitted general health claims for food products, but sought to prohibit any specific claim that a food or food component would prevent a particular disease (Hutt, 1986). Following publication of a major report to the American Heart Association in August 1957 recommending a reduction in dietary cholesterol and saturated fats, labeling and advertising claims for common food products made reference to this new information. Faced with these claims, FDA sought to prohibit any reference to cholesterol or saturated fat, considering such reference as "nutritional quackery." As time wore on, however, and the scientific evidence became more compelling, increased pressure was placed on the agency to change its position. By the late 1960s, FDA continued to adhere to its policy in public, but took relatively little legal action to enforce it.

The White House Conference on Food, Nutrition, and Health

President Nixon announced a White House Conference on Food, Nutrition, and Health in May 1969. The conference was held in December 1969, and the final report was issued in early 1970 (White House Conference, 1970).

Although the White House Conference was convened in response to charges of hunger and malnutrition in America, and not to consider regulatory issues, its conclusions had a dramatic and unexpected impact on FDA policy in regulating food misbranding. The highly restrictive approach to food standards, imitation labeling, special dietary foods, and nutrition claims that was the subject of the formal public hearing conducted by FDA during 1968 and 1969 was thoroughly criticized and rejected. The White House Conference report emphasized the need for sound nutrition, the capability of modern food technology to provide products to fill that need, and the use of increased public information about nutrition, rather than the problems of nutrition quackery.

Release of the report coincided, moreover, with a major change in FDA personnel. Those who had determined the FDA food regulatory approach during the 1960s were gone from the agency when the administrative hearing of 1968-69 was completed and the matter was ready for a final decision in the early 1970s. Many who formed the new leadership in FDA during the early 1970s had participated in the White House Conference. Within 18 months, five individuals who had helped shape the conference policy and prepare the report had left their former positions to join FDA and were ready to implement the regulatory recommendations of the report: James D. Grant, Deputy Commissioner of FDA; Virgil O. Wodicka, Director of the Bureau of Foods; Ogden C. Johnson, Director of the Office of Nutrition in the Bureau of Foods; Allan L. Forbes, Deputy Associate Director of the Office of Nutrition; and Peter Barton Hutt, FDA Chief Counsel. As a result, FDA policy changed dramatically. When Virgil Wodicka left FDA, he was ultimately replaced as Director of the Bureau of Foods by Sanford A. Miller, who had also participated in the White House Conference.

1969-89

The White House Conference represented the end of the restrictive approach to food regulation proposed by FDA during the 1960s. In its place emerged a number of new regulations, based largely on food labeling requirements rather than on rigid standards for product composition.

1. Mandatory Food Labeling Information. The same four statutory categories of mandatory information remain. In two respects, however, they have been changed to reflect the new emphasis on provision of adequate information to consumers rather than on establishing rigid standards for product composition.

Under the FD&C Act, a standardized food is not required to include on the label any mandatory ingredient in the food, and is required to include on the label only those optional ingredients that are specified as required to be labeled under the standard. Pursuant to its policy of encouraging full labeling for all food products, FDA urged food manufacturers and distributors to include in the statement of ingredients both mandatory and optional ingredients [37 Fed. Reg. 5120, March 10, 1972, 21 CFR 101.6(a)], and began systematically to amend all existing food standards to make as many "mandatory" ingredients optional as possible and to require the labeling of all optional ingredients [21 CFR 101.6(b)].

FDA also promulgated new regulations governing the labels to be used on the labels for food products. The new regulations emphasized that a food name must accurately identify or describe the basic nature of the food or its characterizing properties or ingredients, and distinguish the food from different foods [37 Fed. Reg. 12327, June 22, 1972; 38 Fed. Reg. 6964, March 14, 1973; 21 CFR 102.5(a)]. Related regulations provided for inclusion, as part of the food name, the percentage of any characterizing ingredient, or a statement that the food does not contain ingredients that might otherwise be expected [21 CFR 102.5(b) and (c)]. Specific regulations have been promulgated for particular foods, applying these rules [21 CFR Part 102].

2. Food Standards. In the early 1970s, FDA began a systematic amendment of all existing food standards to eliminate the old "recipe" approach and to permit any "safe and suitable" functional ingredient. Accordingly, it no longer necessary to amend existing food standards to permit the use of new food additives and color additives once they have been approved as safe for use.

Since 1970, FDA has not proposed or promulgated new food standards. In a number of instances where food standards had been proposed in the past, they were replaced with regulations that simply establish the name of the food, pursuant to the regulations discussed above. This approach has permitted greater flexibility in food labeling and food formulation.

As a related policy, FDA has abandoned its old position that any resemblance of a new food to a traditional standardized food, or any reference to a standardized food in the name for a new food, automatically renders the new
Regulating the Misbranding of Food (continued)

food illegal. For example, FDA has stated that “raisin bread
made with enriched flour” does not violate the raisin bread
macaroni products with fortified protein” does not violate
the enriched macaroni standard [43 Fed. Reg. 11695, March
21, 1978]; “tomato juice enriched with vitamin C” does not
3, 1974]; and “goat’s milk yogurt” does not violate the yo­
gurt standard (Lake, 1986). Although the precise food name
that will satisfy this new policy often results in substantial
contention among FDA, the traditional food industry, and
the new food manufacturer, this represents a major change
from the restrictive approach pursued by FDA until the
1970s.

The limitation of fortification to listed foods, within
specified levels, was totally abandoned. Fortification of
standardized foods was permitted, where no enrichment
standard already existed. Limitations on fortification were
implemented through the promulgation of nutrition quality
guidelines [21 CFR Part 104] and a general statement of
fortification policy [39 Fed. Reg. 20900, June 14, 1974; 45

Finally, FDA adopted new regulations governing nutrition
labeling for all food [37 Fed. Reg. 6493, March 30,
March 14, 1973; 21 CFR 101.9]. Except for bread
products that must be enriched under state laws, it is not

This continuing review and revision of food labeling policy
reflects the dynamic relationship between food technology and food
law policy. It assures that, as science progresses, FDA
regulatory policy will keep pace.

...
major problem, and thus no such regulations have been promulgated.

Policy Reflects Dynamic Relationship

No food labeling policy can be permanent. As new scientific information is obtained, food labeling requirements must change accordingly. Thus, refinements in current FDA policy were considered in 1979 (38 Fed. Reg. 7590; Dec. 21, 1979); regulations were adopted in 1984 to govern sodium labeling (147 Fed. Reg. 26580, June 18, 1982; 49 Fed. Reg. 15510, April 18, 1984); and regulations were proposed in 1986 to revise the current provisions for cholesterol and fatty acid composition labeling (51 Fed. Reg. 42584, Nov. 25, 1986). This continuing review and revision of food labeling policy reflects the dynamic relationship between food technology and food law policy. It assures that, as science progresses, FDA regulatory policy will keep pace.

References


From Wisconsin's Meadowlands comes . . .

Dried Cream Extract

The highly concentrated flavor of milk fat. So concentrated, one pound equals the flavor of 80 pints of cream . . . at an equivalent cost of less than 5¢ per pint!
100% natural . . . Water-soluble powder . . . Requires no refrigeration.
Add to icings, sauces, dessert mixes, candy, soup . . . anywhere natural cream flavor and richness is desired.

Circle reader service number for complete information

FOR FASTER ACTION CALL US TODAY AT 1-800-426-1119

Food Ingredients Division, Cumberland Packing Corporation, Racine, WI 53403
Phone (414) 637-9288
Fax 414-637-7983

For information circle 146
Regulating the Safety of Food
Roger D. Middlekauff

The American public demands food that is colorful, flavorful, nutritious, inexpensive, consistently high in quality, conveniently packaged, readily available, clearly and informatively labeled, and—above all—safe. Clearly, a fundamental motivating factor in Congress' enactment of the Food and Drugs Act of 1906, and its successors, was the need to assure the United States consumers that the food supply would be safe. In this respect, the average consumer may be satisfied that he or she clearly understands the meaning of the term "safe." In contrast, those who are involved in food regulatory activities consider the term "safe" an elusive concept as they carry out their task of taking this conceptual idea to a definable limit.

Implementation of the 1906 Act and its successors was delegated by Congress first to the U.S. Dept. of Agriculture and eventually to the Food and Drug Administration. The interpretation of the Act and application of its terms to the food supply was complicated by changing technology in the manufacture of food, increases in amounts of food processed, changes in types of food consumed, available analytical techniques, and improvements in toxicological sciences. Rather than describe in detail all these events, a chronology of major events associated with implementation of the safety of food is presented in Table 1, with supplemental information in this text which describes and interprets in broad terms the changes which have occurred.

Food and Drugs Act of 1906

The 1906 Act sought to protect the public health by prohibiting the marketing of "adulterated" food. At that time, common food products were modified by the addition of a variety of ingredients designed to give a false appearance or taste and to dilute the quality of the products. The 1906 Act was a manifestation of the grave concern over this widespread contamination of the food supply; it was enacted to resolve the main key issues of that era.

The Act declared as "adulterated" food that contained "any added poisonous or other added deleterious ingredient which may render such article injurious to health." Over time, this initial legislative effort was found to have several serious limitations, not the least of which was the difficulty in developing evidence that would prove that a substance was in fact "injurious to health." Accordingly, Congress enacted several amendments, designed to strengthen and clarify the applicable law. They were eventually followed by a comprehensive revision titled the Federal Food, Drug, and Cosmetic Act of 1938.

Federal Food, Drug, and Cosmetic Act of 1938

The 1938 Act continued to rely on the concept of "adulteration," but expanded its applicability by describing in a more elaborate form the various activities which would fall within that prohibition. As in the 1906 Act, the 1938 Act declared adulterated any food which "bears or contains any poisonous or deleterious substance which may render it injurious to health," with the additional point, "[b]ut in case the substance is not an added substance such food should not be considered adulterated under this clause if the quantity of such substance in such food does not ordinarily render it injurious to health." Thus, a distinction was established between those constituents of a food which are inherent and those constituents which are added. The Act represented the Congressional view that the public is willing to accept more risk from nature's own foods.

FDA has defined by regulation the procedures for regulating food contaminants and naturally occurring poisonous or deleterious substances in food. The regulation states that the test of whether a substance is "added," as opposed to "naturally occurring," depends on the level of the substance that is intrinsically a part of the food. Such a substance becomes of concern when the amount present in the food exceeds the level considered as the "naturally occurring" level, whether or not the additional amount present is the result of some form of human intervention. Regarding contamination, FDA recognizes that it is not possible to produce food or food ingredients that are entirely free from contamination by foreign substances or impurities. The standard of avoidability is whether the substance may be avoided by good manufacturing practices. FDA has the choice of developing action levels or, alternatively, tolerances under Section 406 of the Act. That section permits FDA to establish a tolerance where the substance is "required in the production" of a food and/or where the substance "cannot be avoided by good manufacturing practice." The former will be more appropriate in dynamic situations where the extent of the avoidability of the substance is changing or where the toxicological data are scanty or conflicting and additional data are being developed.

The 1938 Act also declared a food adulterated if it is a "filthy, putrid, or decomposed substance, or if it is otherwise unfit." This provision both protects the esthetic sensitivities of the consumer and prevents the development of filth and decomposition which could be a public hazard. A food is adulterated if it is unfit for food, even though it may not be filthy, putrid, or decomposed. FDA is not required to demonstrate that the violation is injurious to health prior to its seizing the food. FDA is authorized to set defect action levels but is not required to do so. However, even though a contamination is below the defect action level, FDA may still seize the food if it has been made under insanitary conditions. Nor does FDA generally permit blending of contaminated with uncontaminated food to bring the combination below the defect action level. Also, an animal that is diseased or dies other than by slaughter is also considered adulterated, whether or not the food is actually unfit.

The Act declared as adulterated any food prepared, packed, or held under insanitary conditions. The adultera-
tion occurs whether or not any actual contamination occurs. Although the insanitary conditions may not have rendered the food injurious to health or otherwise unsafe, adulteration has nevertheless occurred. Where the food has not been contaminated by the conditions, this serves as evidence that the conditions would not likely cause contamination. Despite repeated challenges as to the vagueness of the terms “filthy,” “insanitary,” and “insanitary conditions,” the courts have held those terms to be clear and without need for explanation. Pursuant to this provision, FDA has promulgated general Good Manufacturing Practices (GMP) regulations.

The GMPs provide requirements regarding several facets of the manufacturing process. Included, for example, are requirements regarding cleanliness, education, training, supervision, and freedom from communicable disease. The buildings, facilities, and equipment must be adequately cleanable, properly designed and maintained to prevent the adulteration of food. Also important are the appropriate development and application of quality control procedures.

A food is also considered under the Act to be adulterated if a “valuable constituent” has been omitted. Similarly, a food is adulterated if another substance has been substitut-

Congress . . . changed the traditional requirement that FDA prove adulteration, by establishing the then novel approach that industry must prove safety.
Table 1—Some Significant Events in the regulation of food safety

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1785</td>
<td>First general food law in the United States enacted in Massachusetts</td>
<td>Massachusetts Act (1785)</td>
</tr>
<tr>
<td>1886</td>
<td>First federal law dealing with color—the Oleomargarine Act—enacted</td>
<td>U.S.C. (1886)</td>
</tr>
<tr>
<td>1899</td>
<td>Senator A.S. Paddock of Nebraska introduces the first bona fide pure food bill to be considered by Congress</td>
<td>Wiley (1930)</td>
</tr>
<tr>
<td>1902</td>
<td>Dr. Wiley’s “poison squad” over five years tests boric acid, salicylic acid, sulfuric acid and sulfites, benzoic acid, formaldehyde, copper sulfate, and salt peter</td>
<td>Wiley (1930)</td>
</tr>
<tr>
<td>1906</td>
<td>Pure Food and Drugs Act of 1906 and Meat Inspection Act of 1906 enacted</td>
<td>U.S.C. (1906a; b)</td>
</tr>
<tr>
<td>1914</td>
<td>U.S. Supreme Court interprets “may render . . . injurious to health” as applying not to the additive but to the food itself</td>
<td>U.S. Supreme Court (1914)</td>
</tr>
<tr>
<td>1927</td>
<td>Food, Drug and Insecticide Administration (renamed Food and Drug Administration in 1931) becomes a separate unit of the U.S. Dept. of Agriculture</td>
<td>U.S.C. (1927)</td>
</tr>
<tr>
<td>1940</td>
<td>FDA transferred from USDA to Federal Security Agency (predecessor to U.S. Dept. of Health and Human Services)</td>
<td>Office of the President (1940)</td>
</tr>
<tr>
<td>1948</td>
<td>Congress gives FDA jurisdiction over products that become adulterated after interstate shipment and at all levels of distribution, including retailing</td>
<td>U.S.C. (1948)</td>
</tr>
<tr>
<td>1950</td>
<td>Two artificial sweeteners—Dulcin and P-4000—banned under Section 402 (a)</td>
<td>FDA (1950)</td>
</tr>
<tr>
<td>1953</td>
<td>Congress gives FDA authority to inspect a plant, after written notice to the owner, without a warrant and without permission of the owner</td>
<td>U.S.C. (1953)</td>
</tr>
<tr>
<td>1954</td>
<td>Pesticide Chemical Amendment of 1954 enacted to bar pesticide residues that do not conform to a tolerance established under section 408</td>
<td>U.S.C. (1954)</td>
</tr>
<tr>
<td>1959</td>
<td>Cranberry sales halted prior to Thanksgiving Day because of alleged contamination by herbicide</td>
<td>U.S.C. (1959)</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
<td>Reference</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>1967</td>
<td>Delaney clause first invoked, to ban Flectol H, a component of food packaging adhesives</td>
<td>FDA (1967)</td>
</tr>
<tr>
<td>1969</td>
<td>Good Manufacturing Practices regulations first adopted</td>
<td>FDA (1969a)</td>
</tr>
<tr>
<td></td>
<td>Cyclamates banned on the basis of carcinogenicity</td>
<td>FDA (1969b)</td>
</tr>
<tr>
<td></td>
<td>Clostridium botulinum type B found in Bon Vivant canned vichyssoise</td>
<td></td>
</tr>
<tr>
<td>1972</td>
<td>Unavoidable natural defect guidelines (“filth guidelines”) first released to public</td>
<td>FDA (1972)</td>
</tr>
<tr>
<td>1975</td>
<td>Corporate officer criminally convicted for sanitation problem in food-containing facility</td>
<td>U.S. Supreme Court (1975)</td>
</tr>
<tr>
<td>1976</td>
<td>Provisional listing of carbon black terminated because of suspicion that it contains carcinogenic compounds</td>
<td>FDA (1976)</td>
</tr>
<tr>
<td>1977</td>
<td>Provisional listing of graphite terminated because of suspicion that it contains carcinogenic compounds FDA proposes to ban use of saccharin Congress allows continued use of saccharin despite FDA’s proposed ban</td>
<td>FDA (1977a)</td>
</tr>
<tr>
<td></td>
<td>FDA proposes to ban use of saccharin FDA adopts regulation governing action levels and tolerances for poisonous and deleterious substances, stating that any substance which is not an “inherent” constituent of a food may be regulated as an “added” substance</td>
<td>FDA (1977b)</td>
</tr>
<tr>
<td></td>
<td>FDA applies de minimis exception to Delaney clause to color additive in its entirety U.S. Supreme Court interpreted application of 21 U.S.C. 346 in regard to tolerance levels for aflatoxin</td>
<td>FDA (1977c)</td>
</tr>
<tr>
<td>1979</td>
<td>U.S. Court of Appeals for the District of Columbia states that FDA has administrative discretion in de minimis situations</td>
<td>D.C. Circuit Court (1979)</td>
</tr>
<tr>
<td>1982</td>
<td>FDA announces constituents policy for regulating carcinogenic chemicals and first applies it to D&amp;C Green No. 6 FDA releases to public defect action levels for filthy, putrid, or decomposed substances in food</td>
<td>FDA (1982a)</td>
</tr>
<tr>
<td></td>
<td>FDA proposes de minimis exception to Delaney clause for a food additive in its entirety, to allow continued use of methylene chloride to decaffeinate coffee</td>
<td>FDA (1982b)</td>
</tr>
<tr>
<td>1985</td>
<td>FDA proposes de minimis exception to Delaney clause for a food additive in its entirety, to allow continued use of methylene chloride to decaffeinate coffee</td>
<td>FDA (1985)</td>
</tr>
<tr>
<td>1986</td>
<td>FDA states that food produced by new biotechnology could result in a level of substance that “may be injurious to health” FDA applies de minimis exception to Delaney clause to color additive in its entirety U.S. Supreme Court interpreted application of 21 U.S.C. 346 in regard to tolerance levels for aflatoxin</td>
<td>FDA (1986a)</td>
</tr>
<tr>
<td></td>
<td>FDA proposes de minimis exception to Delaney clause to color additive in its entirety U.S. Supreme Court interpreted application of 21 U.S.C. 346 in regard to tolerance levels for aflatoxin</td>
<td>FDA (1986b)</td>
</tr>
<tr>
<td>1987</td>
<td>FDA states that food produced by new biotechnology could result in a level of substance that “may be injurious to health” FDA proposes de minimis exception to Delaney clause to color additive in its entirety U.S. Supreme Court interpreted application of 21 U.S.C. 346 in regard to tolerance levels for aflatoxin</td>
<td>FDA (1986a)</td>
</tr>
<tr>
<td></td>
<td>FDA proposes de minimis exception to Delaney clause to color additive in its entirety U.S. Supreme Court interpreted application of 21 U.S.C. 346 in regard to tolerance levels for aflatoxin</td>
<td>FDA (1986b)</td>
</tr>
<tr>
<td>1988</td>
<td>FDA announces cooperative agreement to establish a National Center for Food Safety</td>
<td>FDA (1988)</td>
</tr>
</tbody>
</table>
ed in whole or in part for an ingredient. In both cases, the result of the omission or substitution is unimportant. These provisions have been employed by FDA to regulate the formulation of foods that do not have standards of identity—but not without some difficulty, since the term "valuable constituent" is somewhat ambiguous and depends on the representations made for the product, the role of the ingredient in the food, and the level of the constituent in the food.

The Act provides that a food is adulterated if damage to or inferiority of the product has been concealed; if something has been added to the food to make it seem bigger, heavier, better, or of greater value; or if something has been added to reduce its quality or strength. The safety of the resulting product is not an issue under this provision. There must be proof that the ordinary consumer under usual retail circumstances is likely to mistake the inferior product for the product which it purports to be.

In some aspects, the potency of many of the provisions of the 1938 Act have survived throughout the years. However, other provisions have had to be improved through substantial amendments to the Act.

From "Adulteration" to "Safety"

After several years of application, interpretation, and enforcement of the Act, a significant revision took place. The Food Additives Amendment of 1958 established the requirement of "safety," which led to a major change in FDA's approach to its activities. Congress applied the term "safe" as the criterion for action, thereby supplementing, but not replacing, the use of the term "adulteration." The result was a shift in focus—from an approach which emphasized evaluation of the food in its entirety to one which emphasized evaluation of individual food components. Perhaps, in time, FDA might have applied its administrative discretion under the "adulteration" provision to reach the same point that it attained under the provisions requiring "safety," but the Congressional authority allowed FDA to bypass what might have been a somewhat tortuous process.

Congress described the term "safety" as "reasonable certainty that no harm will result from the proposed use of an additive," recognizing that it is not possible to prove that no harm will result under any conceivable circumstances. However, it was generally interpreted to mean that if an additive is safe, there is no risk associated with it. Accordingly, the amendment directed FDA to consider consumption patterns, the cumulative effect of the ingredient in the diet of man or animals, and appropriate safety factors.

Under the Food Additives Amendment, FDA's regulatory activities became divided between continuing the past practices which relied on the prohibitions against adulteration under Section 402 and the even more elaborate procedures under the new provisions of the Act in Section 409, until the activities under Section 409 nearly eclipsed those under Section 402. Section 409 allows FDA to stretch its scientific capabilities, challenging FDA to apply the authors of the new provisions of the Act in Section 409 to the same point that it attained under the provisions requiring "safety," but the Congressional authority allowed FDA to bypass what might have been a somewhat tortuous process.
Regulating the Safety of Food (continued)

amendment), it would not be considered a food additive and would not necessitate a petition and regulation for its use. A prior-sanctioned ingredient would continue to be subject to the “adulteration” limitations of Section 409. The second grandfather clause defined a category of substances which would not be considered food additives on the basis of general recognition of safety by the scientific community. The “generally recognized as safe” (GRAS) status would derive from demonstrable common use in food prior to 1958 or from scientific data which demonstrated its safety. Rather than be subjected strictly to the limitations of the “adulteration” provisions or the same requirements that are applied to food additives, GRAS ingredients are subjected to very ambiguous standards of “general recognition of safety.”

In an effort to bring some standardization of approach to GRAS ingredients, FDA has tried by regulation to make more specific the criteria by which GRAS status will be determined and the standard of safety which will be applied. Despite these efforts, there still remains a wide variance of view as to when a substance is GRAS and whether the GRAS determination should be made by a select group of scientists, by the community of scientists, or by FDA.

The Delaney Clause

While the Food Additives Amendment has had in general a major impact on FDA’s review process for food ingredients, the Delaney clause in that amendment has had an even more significant impact on the regulation of carcinogens. The Delaney clause placed a spotlight on carcinogens. It has served as a driving force in formulating a better understanding of the mechanisms of carcinogenicity as it relates to food ingredients. While a somewhat similar treatment is now accorded carcinogens by other federal agencies, such as the Environmental Protection Agency and the Occupational Safety and Health Administration, the highly focused attention given to carcinogens is no doubt due in substantial measure to the Delaney clause.

In the mid-1960s, scientists postulated that carcinogenicity studies in animals may have some relevance to carcinogenicity in humans. At the outset, the concept was introduced as a qualitative consideration, with extensive admonitions as to the risks of applying any quantitative considerations when making a comparison between the observed effect in test animals and the predicted effect in humans.

Over time, as more carcinogenicity studies in animals were conducted, data were accumulated and efforts were begun to interpret the differences in effects between carcinogens and their possible relevance to humans. Theories were developed comparing the relative intensity of impact of various chemicals. Mechanisms of action were identified; differences were noted, depending on the levels and types of exposure. Throughout the process of accumulating these data, the lingering issue has been the relevancy of those findings to the consuming public in the U.S.

Application of the Delaney clause resulted in a further sophistication in the evaluation of the safety of food ingredients. Instead of evaluating the safety of ingredients in use, FDA began to apply an analysis employing risk assessment principles. As a natural progression, the development of quantitative risk assessment followed the process of statistically relating (1) a lifetime study in a rodent species at a high level of exposure to (2) a lifetime study in humans at normal dietary exposures. All the complicated aspects of carcinogenicity became relatable in simple, comprehensible numbers. The biological information could be expressed in mathematical constructs.

The initial interpretations of the Delaney clause accepted it as an absolute prohibition against food additives which were shown to have caused cancer. These interpretations were dependent on the “no-threshold” or “one-molecule” theory of carcinogenicity. If a substance had a structure similar to a known, probable, or even possible carcinogen, it became suspect and a carcinogenicity study was required. Screening tests were developed, with the view that they might easily and quickly identify suspect carcinogens. As a parallel event, chemists had developed analytical tools which identified substances at astonishingly low levels. The effective result of these activities was the realization that many noncancerous substances were being unnecessarily condemned and the entire food supply could be found questionable. These activities could thereby jeopardize the confidence of the American public in the food supply. Thus began the process to separate risks from nonrisks.

Carcinogens were found to have different mechanisms of action—some were initiators of carcinogenicity, others simply promoted the development of tumors. A regulatory distinction was developed between those two types of substances. Where the mechanisms of action were applicable only to the rodent species being tested, not to humans, another basis for distinction was found. Furthermore, because of the relative difference between the exposure of the rodent and the estimated exposure of humans to the substances, a quantitative comparison was possible—the risk could be numerically extrapolated to humans. By basing the degree of hazard on the level of exposure, an assessment of the extent of risk was possible. A “reasonable certainty of no harm” could be defined in mathematical terms.

Having reached a point of confidence in its ability to evaluate the risks associated with carcinogens, FDA reconsidered its traditional interpretation of the Delaney clause. From a blanket prohibition, the clause was reinterpreted to apply in a limited fashion. To start with, FDA stated that several bills have been introduced . . . to carve out an exception to the Delaney clause for insignificant or negligible risks. Until Congress is satisfied that voting for such a bill would not in any measurable way increase the public’s risk, there is little likelihood of passage.
Regulating the Safety of Food (continued)

the clause was not applicable to carcinogenic impurities or by-products in the food additive when a quantiative risk assessment demonstrated an estimated de minimis impact on humans. Then, FDA proposed that the Delaney clause would not bar an animal carcinogen from use as a food additive when a quantitative risk assessment indicated only a de minimis risk of cancer to humans.

In anticipation of a court test of that principle as it applied to color additives, FDA reinterpreted the Delaney clause as stating that the substance is neither a carcinogen in animals nor a carcinogen in humans if a quantitative risk assessment indicated a one-in-a-million risk to humans. Upon review by a federal court, the decision was made that de minimis was not an exception to the Delaney clause as it applied to color additives. However, the door remains open to the possibility that the Delaney clause does not bar the regulation of a food additive which is demonstrated to be a carcinogen with only an insignificant or de minimis cancer risk.

In recent years, several bills have been introduced in Congress which propose to carive out an exception to the Delaney clause for insignificant or negligible risks. Until Congress is satisfied that voting for such a bill would not in any measurable way increase the public's risk, there is little likelihood of passage.

The Future of the Food Laws

During the transition from application of the term "adulteration" to application of the term "safety," the evaluation process changed to one which considered the ingredients in the context of "risk." The refinement of the evaluation process has yet to be so effective as to precisely determine the actual risk caused by ingredients and food products in all patterns of consumption and in all circumstances of use. To accomplish this task, greater scientific efforts will need to be initiated.

Even once actual risks can be estimated or established with reasonable certainty, whether the public will accept that information remains a question. The public's perception of risks associated with food is influenced by many subjective considerations as well as by external forces over which there may be little or no control. In a highly developed society where the choice of foods is essentially unlimited, the control of the public's dietary intake is more a matter of persuasion and education. Included in that education process will be the issue of whether the public will accept the realization that, as in all aspects of life, the food supply cannot be risk free.

Accordingly, there is a predictable continuing conflict that will require many years to resolve, namely, that regulatory activity must continually be adjusted to obtain a compromise between scientific realities and the public's demands. Resolution of this conflict is complicated by a public mood which fluctuates, a public perception which is not consistent throughout the population, and a public view which is difficult to measure.

Needless to say, development of an improved regulatory process is subject to the same limitations which have slowed past development. There is a long lead time between recognition of an issue and the implementation of the steps to resolve that issue. Often, effective action is taken only after a crisis has occurred.

FDA's responsibilities will be focused not only on carcinogens. FDA will be expected to apply attention to microbial contamination, defects in food, pesticide residues, and other types of health effects. Throughout this process, FDA should be encouraged to improve its evaluation process so as to permit additional ingredients to be incorporated into the food supply. New food products and food ingredients are being developed and will continue to be developed. If FDA is unable to provide adequate guidance and a prompt review of these products, its credibility and its respectability will suffer, making its task even more difficult.

To further complicate FDA's tasks, foods are being moved throughout world markets in ever-increasing amounts, rather than being shipped solely within individual countries. Consequently, a continuing effort is needed to harmonize the regulatory views of countries throughout the world, rather than for each country to establish its own, limiting requirements. These tasks will continue to challenge the competence, creativity, and patience of those responsible for the safety of the food supply—both those who regulate and those who are subject to the regulations.

The Role of Other Agencies

While FDA has major responsibilities over the food supply in the U.S., other federal and state agencies also have a significant regulatory role over various foods, beverages, and related products. The regulatory programs have developed in scope since the beginning of this century. Paralleling the development of a statutory and regulatory scheme governing foods and drugs, Congress began early in the 20th century to enact legislation which implemented effective meat and poultry inspection programs.

The problem of the unseen dangers in the meat supply was vividly and lastingly brought to the attention of the American public by the renowned book, The Jungle, by Upton Sinclair. Within a year after publication of the book, the Meat Inspection Act of 1906 (U.S.C., 1906b) was passed by a shocked Congress. The Act mandated the postmortem inspection of the carcasses of cattle, sheep, swine, and goats prepared for consumption and for transportation in interstate commerce. After a few minor amendments during the ensuing years, the Wholesome Meat Act of 1967 (U.S.C., 1967) was enacted. This Act significantly strengthened the effectiveness of the inspection programs, imposing a common standard of inspection and quality on nearly all the red meat produced in the U.S. USDA was also given sweeping authority over meat and meat products, from the packinghouse to the grocery store.

After many years of a voluntary poultry inspection program within USDA, the Poultry Products Inspection Act (U.S.C. 1957) was enacted in 1957, requiring ante-mortem and postmortem inspection of each bird produced for human consumption. At that point, under the meat and poultry inspection laws, only wholesome, unsalubriated, and properly branded products from sanitary plants could be marketed in the U.S.

USDA's Food Safety and Inspection Service has regulatory responsibility not only for the meat and poultry inspection programs, but also for the Egg Products Inspect-
tion Act (U.S.C., 1970) which covers eggs and egg products and the Agricultural Marketing Act (U.S.C., 1946), which facilitates the trading and marketing of agricultural products in general. USDA's Animal and Plant Health Inspection Service has responsibility for a variety of programs relating to plant health, plant pests and diseases, pest management, and animal disease control.

As fish and fish products have become more widely consumed in the U.S., increasing attention has been given to the need to assure the public of a safe and wholesome supply of these products. The U.S. Dept. of Commerce's National Marine Fisheries Service has established an inspection and grading program for fish products. This program is in part voluntary and the shared responsibility of various state and federal agencies. Proposals have been made to make inspection of fish and fish products mandatory.

The regulation of pesticides used on food is the responsibility of the Environmental Protection Agency under the Federal Insecticide, Fungicide, and Rodenticide Act (U.S.C., 1947), coupled with Section 408 of the FD&C Act (U.S.C., 1938a). EPA has established a comprehensive safety testing program to assure that the pesticides used and the residues remaining on food are safe for humans and generally safe for the environment.

Ingredients in alcoholic beverages and tobacco products are subject to regulation by the U.S. Dept. of the Treasury's Bureau of Alcohol, Tobacco and Firearms. This agency monitors the ingredients used in those products to assure that they comply with applicable standards of safety and that they are consistent with the product standards adopted by the Bureau.

To effectively administer the various Acts, the federal agencies by necessity must work closely with state governments and with each other. Only because of the cooperation which has existed over the years have the agencies been able to carry out their responsibilities successfully, resulting in their being able to continually claim that the American public has access to the safest food supply in the world.

References


Office of the President. 1940. Reorganization Plan No. IV of 1940. Statutes at Large 54: 1234.


—Edited by Neil H. Mermelstein, Senior Associate Editor
The Evolution of Sensory Science (continued from 256)

I and II. CRC Press, Inc., Boca Raton, Fla.

Tilgner, D.J. 1957. "Analiza Organoleptyczna Zywieniowej." Wy-
Top 10 Food Science Innovations 1939–1989
Staff Report

One of the highlights of the Institute of Food Technologists' 50th Anniversary Meeting was the naming of the most significant innovations in food science developed during the 50-year history of IFT. Nominated by the Fellows of IFT, the innovations were judged by the IFT Expert Panel on Food Safety and Nutrition. The ten developments deemed most important were announced during a press conference by Theodore P. Labuza and Fergus M. Clydesdale—IFT President and chairman of the IFT Panel, respectively.

Photos taken during the press conference, quotes of remarks made by Labuza and Clydesdale, and a news release listing the "Top 10" innovations received nationwide attention. In fact, the "Top 10" story received more coverage on radio and television and in newspapers than any other IFT press conference or news release.

Following are the "Top 10" innovations—listed in order of importance—along with a brief description of each:

1. Aseptic Processing and Packaging. This process, developed in the 1940s, is defined as the high-temperature, short-time (HTST) sterilization of a food product independent of the container, the sterilization of the container, and the filling of the product in a sterile atmosphere. It provides increased food quality and retention of nutrients.

Since 1979, the process has developed rapidly and has found wide applications in the processing and packaging of high-acid foods. One of the reasons for the increasing proliferation of aseptically processed and packaged food products during the past ten years is the development of new container materials, such as polymer plastics and polymer-coated paper containers.

In the United States, the process is used primarily for fruit juices marketed in "brick-style" containers known as "juice boxes."

2. Minimum Safe Canning Processes for Vegetables. Although Nicholas Appert developed the canning process between 1775 and 1810, it has been within the last 50 years that food scientists have determined thermal processes needed for the "safe" canning of specific vegetables.

The process depends on determining the product's heat penetration curve and the initial microbial contamination levels at the arrival at the minimum time-temperature combination that will destroy the most heat-resistant pathogens and spoilage organisms. Result of the "safe" process is a "commercially sterile" product, i.e., a product free of pathogens, toxins, and bacteria that could cause spoilage under normal storage conditions during the desired storage life.

3. The Microwave Oven. In 1978, only 10% of U.S. households owned microwave ovens. Today, nearly three of every four U.S. households have them. By the year 2000, household penetration is expected to reach 90%. Food processors in the U.S. have responded to this "microwave revolution" by developing new products and adapting existing ones to meet the present and the anticipated future demands for microwaveable items.

4. Frozen Concentrated Citrus Juices were developed at a U.S. Department of Agriculture research laboratory in the mid-1940s. Key to the original process was the addition of about 7% fresh juice back to the concentrate. Today, processors add essential oils and natural flavors to the concentrate before packaging and freezing.

Frozen concentrated citrus juices lose less than 5% of their vitamin C. Most of the loss occurs during storage, not during processing.

5. Controlled Atmosphere Packaging (CAP) for Fresh Fruits and Vegetables. CAP uses reduced levels of oxygen, selective mixtures of atmospheric gases, or increased concentrations of carbon dioxide to limit respiration and ethylene production, thereby delaying ripening and decaying and increasing the shelf lives of refrigerated products.

Development of packaging systems and films that are selectively permeable to specific gases has been the key element in the commercialization of CAP.

6. Freeze-Drying involves rapid deep-freezing, followed by sublimation of water by heating the frozen product in a vacuum chamber. The first commercial prototype plant for freeze-drying food opened in 1960.

Coffee, the best-known freeze-dried product, retains its original flavor and aroma. When freeze-dried particulate foods—poultry, meats, seafood, and fruits and vegetables—are reconstituted, they exhibit not only their original flavor and aroma, but also their original size, shape, and texture.

7. Frozen Meals. Food research during the last half century has led to the development of new freezing methods and has made possible the prediction of optimal freezing and storage conditions.

Properly frozen and stored foods exhibit negligible nutrient losses.

8. Concept of Water Activity. Only in recent years has a scientific basis been laid for the understanding of the influence of water activity on food product safety, quality, and stability.

Recognition of the importance of water activity has led to the development of improved dehydrated and intermediate-moisture foods. It has also played a key role in the development of modern flexible packaging systems.

9. Food Fortification is the addition of nutrients, including vitamins and minerals, that were not present in a food originally, or were present in insufficient amounts. Milk, flour, ready-to-eat breakfast cereals, cornmeal, grits, pasta, rice, fruit juices, fruit drinks, and other products are commonly fortified.

10. Ultra-High-Temperature (UHT) Processing of Milk and Other Products. The UHT process is a pasteurization treatment that involves heating products at a minimum temperature of 265°F for 1–3 sec. In combination with aseptic packaging, the UHT process results in a category of products usually referred to as "sterilized milk" or "sterilized cream," which can have shelf lives of more than 90 days.

Other Innovations that didn't make the "Top 10" list, but merited mention by the IFT Expert Panel on Food Safety and Nutrition were: polyunsaturated corn oil margarine; fat hydrogenation; high-fructose corn syrup; aspartame; and, extruded food technology.
IFT’s 50th Anniversary Song

The following lyrics were composed for IFT’s 50th Anniversary celebration. A stereo cassette recording of the song, performed by professional vocalists with full orchestration, is available. To order a copy, see p. 125.

“IFT, Inspiration for Tomorrow”

Fifty years have brought us to where we stand today—
An international family; a world technology.
We’ve pledged our hearts and hands to feed the world a better way—
Dedicated to food science, we’re proud to be . . .

IFT, we are the Inspiration For Tomorrow.
IFT, we are the shining stars for all to follow.
With the promise of tomorrow and a past so proud,
Today we are the future—together, IFT.

Another fifty years will take us past where we stand today—
An international family striving toward a brighter day.
Now it’s a time of celebration, a “labor of love.”
On our Golden Anniversary, with pride we say . . .

IFT, we are the Inspiration For Tomorrow.
IFT, we are the shining stars for all to follow.
With the promise of tomorrow and a past so proud,
Today we are the future—together, IFT.
IFT—Inspiration For Tomorrow!

Copyright 1989 Jamie Richardson
IFT 50th Anniversary Meeting
Photo Highlights

The Institute of Food Technologists celebrated its 50th Anniversary in Chicago on June 25-29, 1989. Photographs on this and the facing page highlight some of the tributes paid to IFT's founders, charter members, past presidents, staff, and members during a special program held on Sunday evening, June 25. Photos on the following two pages were taken during the many special events, meetings, symposia, exhibits, and social functions that were part of the 50th Anniversary celebration during the remainder of the 5-day meeting.

André Bolas (above left), chairman of the 50th Anniversary Committee, displays a proclamation from the State of California. IFT President Theodore P. Labuza (above), accepts another from Ellen Craig, Deputy Chief of Staff for Illinois Governor James R. Thompson. Both proclamations designated the week of the meeting as Food Science and Technology Week. Other special awards given to IFT on its 50th Anniversary are shown on pp. 314-315.

Calvert L. Willey (near right), IFT Executive Director Emeritus, and Howard W. Mattson, IFT Executive Director, commended IFT's founders, charter members, and past presidents for their vision and leadership in making IFT the premier international society for food science and technology.

Philip K. Bates, designated responder for the founder members, reminisced about the founding and early years of IFT. Shown at top right are three of the surviving founder members—Bates, Ellery F. Harvey, and Bernard L. Oser (E. Arthur Beavens and Paul F. Sharp were unable to attend). The three founder members are shown with three IFT Student Association representatives (from left) LeeAnne Jackson, U. of Kentucky; Anne Tieleman, U. of Minnesota; and Mark Hines, Purdue U. The founders and students met privately to discuss the past, present, and future of IFT and food science.
Charles F. Niven Jr. represented IFT's past presidents. During his presentation he thanked all past presidents and Calvert L. Willey, IFT Executive Director Emeritus, for their leadership. Photo at far right shows Robert C. Pearl congratulating some of the past presidents who attended the meeting. Photos of all IFT past presidents appear on pp. 26-28.

Celebratory Speaker Richard L. Hall, honored the pioneers in food science and technology. The complete text of his paper begins on p. 186.


—Continued on next page
A Plenary Session covering the past, present, and future of food science and technology in industrialized and developing countries was held on Monday afternoon. Photo at far left shows speaker Samuel A. Goldblith and A.S. Clausi, who presided at the plenary session. Pictured at left are Goldblith and Clausi, along with the three other speakers (from left) Ricardo Bressani, Agide Gergatti-Netto, and Fergus M. Clydesdale. Texts of all four plenary session papers are published in this issue.

International Activities during the 50th Anniversary Meeting included a short course, "The Role of Management in Food Product Quality Assurance Worldwide," a symposium, "International Issues and Regulations Affecting Food Science and Trade," and the George F. Stewart International Research Paper Competition. Photo at near right shows Charles Brokaw, Nathaniel Geary, George Burditt, and Lou Bianco. Brokaw and Bianco were cochairmen and Geary and Burditt were speakers at the short course. Geary holds a flag that flew over the U.S. Capitol building. Photo at far right shows IFT president-elect Paul F. Hopper, presenting a paper during the symposium. Seated is symposium chairman, Herbert Weinstein.

George F. Stewart International Paper Competition dignitaries and winners are shown in photo at right (from left) Kent K. Stewart, Mrs. Kent K. Stewart, Rob Stewart, G.N. Bookwalter, Enrique Marco, Jose M. Aguiler, D.J. Buckley, Mrs. George F. Stewart, Elvira G. Mejia, M.P.N. Real, I. Ekaasiri, F.H. Hoskins, M. Jimenez, and R.P. Betea.

Speakers who presented special 50th Anniversary review papers during technical sessions and IFT Division symposiums included (left to right) J.W. Erdman Jr., Nutrition; P.B. Hutt, Toxicology and Safety Evaluation; S.K. Harlander, Food Biotechnology, and Z.M. Vickers, Sensory Evaluation.
A Meeting of the 50th Anniversary Committee (above left), a Food Packaging Dateline 1989 exhibit (center) which featured the most significant innovations in food packaging during the past 50 years, and a special black tie reception honoring 50th Anniversary donors were other highlights of the 50th Anniversary celebration. Photo at above right shows Robert E. Smith (left), chairman of the 50th Anniversary Industry Recognition Subcommittee, and FDA Commissioner, Frank E. Young, featured speaker at the black tie reception.

The Closing Ceremony on Thursday afternoon was conducted by André Bolaffi (top left), chairman of the 50th Anniversary Committee. Features of the ceremonies included a grand march by representatives of IFT Divisions, STGs, and Regional Sections who carried their organizations' standards (top center), and remarks by Ben F. Buchanan (top right), chairman of the past presidents, founders, and charter members Subcommittee of the 50th Anniversary Committee.

Other Highlights of the Closing Ceremony included the placing of many items illustrating IFT's past, present, and future in a "time capsule" to be opened in 25 years; the "passing of the torch" to IFT Student Association representatives; and the awarding of a door prize. Shown in lower photos left to right are Gilbert A. Leveille placing a copy of the 50th Anniversary commemorative issue of Food Technology in the time capsule; students K. Keating, A. Higgenbottom and L. Jackson accepting the torch from H. Griswold and C.J. Bates, and Executive Director H.W. Mattson, congratulating R.C. Lindsay, winner of a round trip airline ticket for two to anywhere in the U.S.
Special Honors given to the Institute of Food Technologists on its 50th Anniversary

A letter of greetings and congratulations from President and Mrs. George Bush

Illinois House Resolution No. 709 proclaiming Illinois’s “Food Science and Technology Week”, and a welcoming letter from Chicago’s Mayor Richard M. Daley

Proclamations from the governors of the States of Illinois, California, and Minnesota designating IFT’s Annual Meeting week as “Food Science and Technology Week”
Resolutions from the American Chemical Society and the American Society of Agricultural Engineers commending and congratulating IFT on its 50th Anniversary

Plaques and Plates from our affiliated organizations (clockwise from top left) Colombian Society of Food Science and Technology, Chinese Institute of Food Science and Technology, Finnish Society of Food Science and Technology, Mexico Section, Singapore Institute of Food Science and Technology, and the Australian Institute of Food Science and Technology.