Maximizing the Usefulness of Food Microbiology Research

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Funding for food microbiology research often follows disease outbreaks: botulism from vacuum-packed white-fish chubs, listeriosis from soft cheeses, or illness due to *Salmonella* Enteritidis or *Escherichia coli.* As a consequence of research, detection, identification, and subtyping methods improve, and more is learned about pathogenicity and virulence. Research also explores the organisms' capacity to multiply or survive in food and to be killed by established or novel processes. However, rarely is there a critical overview of progress or trustworthy statements of generally agreed-on facts. That information is not maintained in a form that can readily be used by regulatory departments and the food industry to ensure a safe food supply. A centralized system is urgently needed that is accessible electronically and carries information in a standardized format on the essential properties of the organisms, including pathogenicity, methods of detection, enumeration and identification, alternative prevention and control methods, and growth and survival characteristics.

Most countries aim to regulate food and the food industry to ensure a safe and wholesome supply. Although the technology of food processing is based on tradition (drying, freezing, fermentation), research has resulted in a wide range of processes to meet the ever-changing requirements of consumers. Canning of low-acid foods set an enviable example of microbiologic safety. Today, consumers demand less heavily processed foods that contain a minimum of chemical preservatives, have a long shelf life, and are "fresh" yet microbiologically safe. Competitive food retailing requires such products to be no more expensive than existing products. In the United Kingdom, there has been a swing toward convenience foods and foods with ethnic flavors, sometimes with a premium price. Commercial success is evident, but relatively few of those foods have been evaluated experimentally for microbiologic safety. Emphasis is on risk assessment, on Hazard Analysis and Critical Control Points (HACCP) and process control, all of which rely heavily on existing knowledge. That knowledge, and the raw data from which it is derived, could be better organized and easier to use.

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The International Commission on Microbiological Specifications for Foods (ICMSF)

The history of microbiologic aspects of food control is reflected in the publications of ICMSF. ICMSF was established in 1962 as foodborne disease greatly increased microbiologic testing of foods. Increased testing, in turn, created widespread practical and regulatory problems in the international food trade. At that time, analytical methods were not standardized, sampling plans were of doubtful statistical validity, and the interpretation of results applied different concepts of biologic significance and acceptance criteria that confused and frustrated industry and regulatory agencies alike.

ICMSF was founded to assemble, correlate, and evaluate evidence about the microbiologic safety and quality of foods; to consider whether microbiologic criteria would improve and ensure the microbiologic safety of particular foods; to propose, where appropriate, such criteria; and to recommend methods of sampling and examination.

The primary purpose of the commission remains to give guidance on appraising and controlling the microbiologic safety of foods, with due attention to microbiologic quality.

Meeting the commission's objectives would facilitate international trade; the work of national control agencies, the food industry, and international agencies concerned with the humanitarian aspects of food distribution; and the health of consumers.

An advisory body, the ICMSF provides basic information through extensive study and experience and makes recommendations, without prejudice, based on that information. Results of the studies are published as books or papers.

At its meetings, the ICMSF functions as a working group. Its membership consists of 18 food microbiologists from 11 countries whose interests include research, public health, official food control, education, product and process development, and quality control. Members are from government laboratories in public health, agriculture, and food technology; universities; and the food industry. ICMSF also seeks assistance from consultants specializing in particular areas of microbiology. Four subcommissions (Balkan and Danubian, Latin American, Middle East and North African, and Southeast Asian) promote activities similar to those of ICMSF among food microbiologists on a regional scale and facilitate worldwide communication.

ICMSF raises its own funds and pays for its activities and meetings. The commission obtained support from government agencies, the World Health Organization, International Union of Microbiological Sciences and International Union of of Biological Sciences, and the food industry (more than 80 food companies and agencies in 13 countries).

During its first 25 years, ICMSF devoted the major portion of its effort to methodology research, improved standardization of methods, and 17 refereed publications (1). One important finding was that in analyzing salmonellae, samples could be composited, making it practical to collect and analyze the large number of samples recommended in some stringent sampling plans. With the evolution of alternative methods, rapid test kits, and the everexpanding list of biologic agents involved in foodborne illness, the commission reluctantly discontinued its program of comparison and evaluation of methods.

The long-term objective of enhancing the microbiologic safety of foods in international commerce was addressed initially in books recommending uniform analytical methods (2), sound sampling plans and criteria (3), and the microbial ecology of foods (4,5), which familiarized the analyst and food technologist with processes used in the food industry and foods submitted to the laboratory. Knowledge of the microbiology of major foods and the factors affecting their microbial content helps interpret analytical results.

At an early stage, the commission concluded that no food sampling plan could ensure the absence of a pathogen. Testing foods at ports of entry, or end-product testing elsewhere in the food chain, cannot guarantee food safety. This led the commission to investigate the potential value of HACCP for enhancing food safety. A joint ICMSF/World Health Organization meeting in 1980 led to a report on the use of HACCP for controlling microbiologic hazards in food, particularly in developing countries (6-8).

The commission published the principles of HACCP and procedures for developing HACCP plans (9); the publication discussed the relative importance of controlling the production and harvesting, preparing, and handling of foods. Recommendations are given for the application of HACCP at each step in the food chain—from production and harvest to consumption.

The commission recognized that a major weakness in the development of HACCP plans is hazard analysis; knowing about the many biologic agents responsible for foodborne illness has become difficult. The commission's latest book (1) proposes to facilitate the development and assessment of HACCP plans, improve the safety of foods, and facilitate risk assessment. A thorough concise review of reports on growth and death responses of foodborne pathogens, it is intended as a relatively quick reference manual to assist in making decisions. The commission is revising Microbial Ecology of Foods: (Vol. 2) Food Commodities with publication planned as Microorganisms in Foods 6 in late 1997.

ICMSF submitted its recommendations for sampling foods and acceptance criteria for *Listeria monocytogenes* to the Secretariat of Codex Alimentarius in 1993. To stimulate discussion, the recommendations were initially provided to the Codex; they were subsequently published (10) and revised after further discussion (11). At the request of the Secretariat of Codex, the commission developed recommendations for the revision of Principles for the

Establishment and Application of Microbiological Criteria for Foods, which appears in the Procedural Manual of Codex.

Members of ICMSF believe that the original objectives of the commission still apply. The formation of the European Union, the many other worldwide political changes, the growth of developing countries seeking export markets, and the increased worldwide interest in international trade, as evidenced by the passage of the General Agreement on Tariffs and Trade and the North American Free Trade Agreement, all point to the continuing need for unprejudiced guidance and advice. Import and export policies must be as uniform as possible and based on scientific facts. The commission will strive to meet this goal through a combination of educational materials, promotion of HACCP, and recommendations, where appropriate, of sampling plans and microbiologic criteria. In addition, commission members will continue to transfer information on food safety through symposia, meetings, committee activities, and in their daily work. The future success of ICMSF will continue to depend on extensive support from consultants and those who provide the financial support essential to the commission's activities.

Research and Its Current Uses

Research Procedures and Funding

In most countries, funding for research has become more competitive, and has even decreased in recent years. The following observations are based on experience in the United Kingdom and the European Union.

The researcher first identifies the sources of funds and writes a proposal. If funds are granted, the research proceeds. The output may include confidential reports to the sponsor, refereed scientific publications, and, increasingly, a patent or a licensed process or technique. Because funding has so many different sources, writing proposals takes a substantial proportion of the researchers' time. In many cases, the best researchers also write the most persuasive proposals, but is this an efficient use of the researchers' time?

In the United Kingdom, research generally falls into two categories: research funded by the parent body and research supported by a contract. The Institute of Food Research falls under the Biotechnology & Biological Sciences Research Council (BBSRC), formerly the Agriculture and Food Research Council. A proportion of the institute's funds comes directly from the BBSRC, although these funds are declining and facing increased competition among BBSRC institutes.

In addition, funds may be obtained from the central government: the Ministry of Agriculture, Fisheries, and Food (MAFF) and the Department of Health, both of which have research programs focusing on food microbiology. In addition, Scotland and Northern Ireland have separate research budgets, which traditionally have been spent in those countries. Funds from these sources sometimes support projects for 3 years, but more recently for shorter periods.

The European Union supports research across very wide areas, of which only a small part is food technology and food microbiology, e.g., Food-Linked Agro-Industrial Research, now ended, and European Cooperation in Scientific and Technical Research. European Union programs run for 4 or 5 years, but funding is usually less than 100% (often 50% and dependent on financial support from the institute or on parallel funding from one of the above sources).

In the United Kingdom, research funds from the food industry are usually restricted either to very short trouble-shooting projects or to confidential investigations. MAFF encourages industrial support of research in LINK programs, with the government contributing up to 50% of the total funding, provided that the research contains elements of novelty and a consortium of companies, sometimes only three or four.

Not only is the researcher faced with attracting funds from a variety of sources, but the requirements of those funding sources differ greatly. Research on genetic or physiologic reasons for phenomena, such as the unusual acid tolerance of Vero cytotoxin-producing *Escherichia coli* strains, might meet BBSRC's stringent requirements of scientific quality. MAFF publishes a Requirements Document each year, identifying areas and topics that fit into its policy to maintain a safe and wholesome food supply. Some of the research is basic science, e.g., developing novel methods of detecting or identifying microbes; some is more mundane, e.g., improving the effectiveness of sanitizing surfaces in food processes. MAFF also supports a limited program of surveillance for particular foodborne pathogens. These funds are available for research institutes, universities, and other laboratories, and proposals are judged by both MAFF staff and independent assessors from outside. Research is organized into programs on hygienic food processing, separation and detection of pathogens and their toxins, physicochemical principles underlying microbial growth, growth conditions for pathogens, ending in 1997-98, and new programs on assessing microbiologic hazards and risks and managing microbiologic hazards and risks of salmonellae and campylobacters in poultry. The Department of Health also supports food safety research—partly as surveillance and partly as programs targeted at a specific organism, e.g., *E. coli* O157:H7. The Department of Health also responds to topics identified by the Advisory Committee on Microbiological Safety of Foods.

University departments in England are subjected to a different form of scrutiny to determine the amount of research funding they receive from the central government, judged by the Higher Education Funding Council for England. The quality of publications is judged against the number of researchers, and the funding is directed toward research excellence. Newly established departments find it difficult to compete.

Research Output

Output from research has been regarded as the report to the contractor, sometimes confidential and sometimes public. More recently, funding agencies have encouraged exploitation of research through patents or licensing agreements. To the researcher, expertise must be recognized through refereed publications. Although in addition to detailed papers, overviews and sometimes summaries for the industry are provided, there is generally less consideration for the research user. In recent years, many reviews have become mere compilations of completed research. Moreover, most computerized databases terminate in about 1970, thus ignoring a wealth of earlier information. HACCP and risk assessment would be greatly facilitated if data on microbial responses (growth, survival, death) were collated in a more standardized form. Details should include the food commodity (e.g., meat, fish, vegetables, or fruit), the subgroup (e.g., for meat, beef, pork, or lamb), and the process applied (e.g., cooked, cured, smoked, or fermented). Details of the packaging should include the pack atmosphere (%CO_2, %O_2, %ballast gas). In the longer term, it might become important to know the exact identity of the organism including serotype, phage type, strain, and, in time, virulence factors and even sequences for 16S rRNA and for toxin genes. Other items that should be tabulated include inoculum concentration; prior history of the inoculum, especially if that history might alter the response; incubation temperature(s); measure of water (% brine, a_w); pH; other factors (e.g., nitrite, sorbate); microbiologic method(s); response (growth rate, D value, time to toxin); and estimate of the reliability of the measures of the responses.

Many readers assume that these details are included in most, if not all, publications. However, our experience in compiling published data for comparisons with models of growth, thermal death, or survival (nonthermal death) illustrates that much desirable information is lacking (12-15). Attempts to define the boundary between growth and no growth are not new (16-19). Despite different methods and strains of microbes, compilations of reported data often show a trend (Figure).

Research Users

Despite an overall neglect of the research user's needs, some useful listings are available

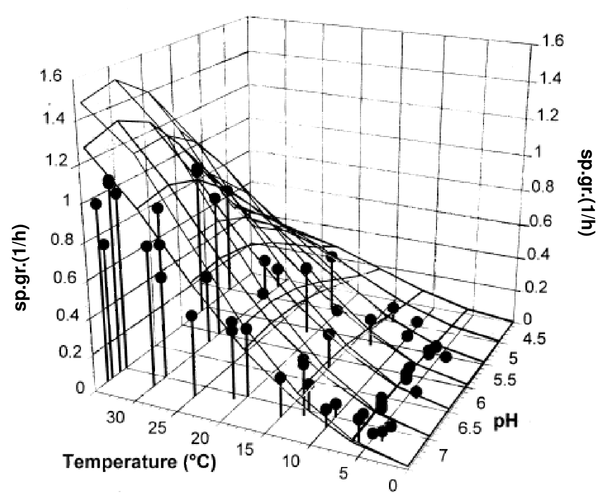

Figure. Specific growth rate of *Listeria monocytogenes* predicted by different models and independent observers (provided by J. Baranyi, Institute of Food Research, Reading Laboratory). Estimates of specific growth rate from published papers are shown vertically. The response surfaces were generated from predictive models and are not a surface fitted to the values.

(20) as are helpful overviews and discussions (21-26). There remains, however, an opportunity for the researcher to make a product more attractive to the research user, e.g., the food industry (both national and international), regulatory bodies, and informed consumers.

Additional Research Needs

Required research includes developing a database of reliable information on microbial responses to food processing conditions. The database needs to be easy to access and use. In addition, because understanding of growth responses and thermal death is greater than our understanding of survival, i.e., little or no loss of viability over many months, we need to have a better understanding of the factors determining that survival and of the underlying microbial physiology. In recent years, we have been faced with such new microbiologic challenges as *Salmonella* Enteritidis Phage Type 4, multidrug-resistant *S.* Typhimurium Definitive Type 104, verocytotoxigenic *E. coli*, Shiga-like toxin-producing *E. coli*, and increasingly vancomycin-resistant *Enterococcus faecium,* and we lack the capacity to anticipate emergence of new pathogens. Finally, new technologies make it possible to study genetic stability and variation in populations, perhaps identifying why particular strains are, or become, more virulent and more pathogenic.

Control of Food Safety

Food safety has traditionally been controlled by inspection and compliance with ordinances or codes of practice. Much faith has been placed in sampling plans and associated microbiologic criteria. However, this approach is retrospective, depending on the microbiologic examination of product that has often been dispatched or consumed. The number of samples that can be examined statistically is too small to detect low levels of "defectives." HACCP was a substantial step forward, with the concept that safety could be designed into a food process. However, HACCP demands substantial knowledge about the characteristics of the food, the process, and the microbes of concern. The knowledge required to implement HACCP effectively is not organized into systems that are easy to use.

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