Introduction

T. McMeekin, University of Tasmania

In the effort to ensure a safe food supply, it is difficult to think of an activity that is as all pervasive as the provision of reliable methods to detect pathogenic microorganisms in foods and food processing environments. This is illustrated well by the observation of Debevere and Uyttendaele (this volume) that:

> Microbiological tests are important in governmental food inspection to enforce legal regulations, in international trade to determine compliance with a microbiological standard, in commercial relationships between trade partners to control on agreed microbiological specifications, in the food industry to maintain quality control and process requirements, in academic laboratories for conducting research, and in reference laboratories to confirm the analyses of another laboratory and to provide surveillance data.

The fundamental requirement to detect a target organism may appear to be a simple task, but the complexity of achieving the basic outcome increases markedly when the method is also required to meet other important requirements. The following criteria are adapted from Table 2.2 in Betts (2002):

- perform with sensitivity, specificity, accuracy, precision, reproducibility and repeatability (see Debevere and Uyttendaele for definitions)
- provide a result within an acceptable time frame, perhaps even in real time
- have ease of use characteristics that allow routine application in industry, including being amenable to automation
- undergo rigorous validation to allow comparison with 'standard' methods
- meet the requirements of laboratory accreditation authorities and gain international acceptance

- be cost effective in terms of both capital outlay and running costs
- provide a numerical estimate of the organism of concern.

This volume is presented in two parts, the first dealing with general issues and the second with the development of particular methods. In the latter, the reader will gain a sense of excitement as researchers describe the latest developments in their fields, many of which arise from technological advances in areas such as molecular biology, microelectronics and information technology. The role of the first part is to put methods development into the framework of approaches to address food safety issues and to consider common requirements and common issues that may limit the efficacy of many methods.

Chapter 1 sets the scene by describing the various roles for microbiological methods in modern food safety management, including prerequisite systems based around good manufacturing practice (GMP) and hazard analysis and critical control point (HACCP) systems. Chapters 2 and 3 deal with key preliminary issues in the use of any microbiological methods: what samples to collect, how to collect them and how to prepare them for analysis. The absolute requirement to understand the implications for adopting a particular sampling method is addressed in Chapter 2 by considering attributes plans and variables plans. The section on how to extract more value from historical test results will be of interest to many laboratories in both the public and private sectors. Chapter 3 reminds readers that many recently developed methods need levels of about 10^5 organisms/ml for reliable detection, indicating a continuing requirement for methods to remove and separate microorganisms from food and concentrate these in samples for analysis. The final two chapters in Part 1 address the very complex issue of providing a level playing field in selecting and judging effectiveness and fairness when the results of different methods, or the same protocol used in different laboratories, are compared.

Part 2 reviews the range of microbiological methods used for detecting pathogenic microorganisms in food. The most traditional method is the use of cultures, discussed in Chapter 6. Samples are incorporated into a nutrient medium and incubated to allow microorganisms to grow to a level where they can be visually identified and counted. Culture methods are technically simple, very adaptable, sensitive and capable of identifying specific organisms. They also allow the analyst to quantify the number of microorganisms present and thus estimate the level of contamination of a sample. Their principal drawback is that they are labour-intensive and time-consuming. However, their ease of use, and the historical reliance of microbiologists on culture-based methods, has spawned a tradition in which they are still widely used in analytical laboratories and continue to provide a standard against which to measure newer techniques.

The modern food industry needs techniques which match the sensitivity of culture methods and their specificity in identifying particular pathogens, but which are faster and capable of being used routinely in industry. The need to develop more rapid and automated methods has led to the emergence of a new generation of analytical techniques that are reviewed in the following chapters. Each method

has its own particular strengths and weaknesses. Some methods may work poorly with certain foods or not be able to identify particular organisms. Some are quantitative, providing a measurement of the number of microorganisms in a sample, whilst others are qualitative, indicating only the presence or absence of a target organism. They also vary in speed and degree of automation in dealing with large numbers of samples and use without specialist microbiological expertise.

Recognition of the need for improved detection technology has often been considered in the food microbiology literature and an account of the perceived needs 10 years ago was provided by Buchanan and Deroever (1993). In evaluating limits in assessing microbiological food safety, these authors highlighted the twin impediments of acquiring and analysing data on the epidemiology of foodborne diseases and limitations in detection methodology. Research into the two issues raised by Buchanan and Deroever, together with the issue of risk assessment, was supported by the US Government in the programme 'Food Safety from Farm to Table'. This programme was reported in the September 1997 issue of *Dairy, Food and Environmental Sanitation* (Anon, 1997); for a comprehensive account of risk assessment as a food safety initiative the reader is referred to Brown and Stringer (2002). Amongst several recommendations for research in the US Government programme, 'Improved Detection Methods' figured prominently with specific activities including detection methods for *Cyclospora*, *Campylobacter, Salmonella, Toxoplasma, Escherichia coli* 0157:H7 and other Shiga-like toxin-producing *E. coli, Cryptosporidium,* hepatitis A and Norwalk viruses, and naturally occurring mycotoxins and marine toxins in foods.

The issue of acquiring and analysing epidemiological data is addressed in Chapter 13 of this volume. This indicates the very marked influence of advances in molecular biology and information technology in providing detailed information on foodborne disease agents and foods involved in their transmission in a time frame allowing interventions to limit the course of an outbreak. This type of technology, also described by Swaminathan *et al.* (2001), will be a major weapon in dealing with the significant change in outbreak scenarios described by Tauxe (1997) with localised, acute events being replaced by diffuse, widespread outbreaks that may even cross national boundaries (Tauxe and Hughes, 1996).

When considering the development of particular methods, Buchanan and Deroever (1993) judged that:

> Even though there has been substantial progress during the last 20 years in the development of rapid methods, no method for the detection of low numbers of pathogens has successfully eliminated the need for a 24 to 48 h enrichment. Although improvements continue, at least for the immediate future, the timeliness of microbiological analyses will remain a major limitation.

Part 2 of this volume suggests that, in the decade since 1993, the pace of new method development has increased significantly and very recent trends indicate

that the rate of this activity is likely to experience a further increase. The search for the 'holy grail' of real time detection of low numbers of pathogens in foods (referred to by Buchanan and Deroever as 'timeliness') will not just be driven by problems of foodborne disease *per se*. New impetus will be provided by the insidious threat of bioterrorism and how this threat could be delivered via contaminated food and water supplies. The international importance of such scenarios will undoubtedly lead to significant investment in research into methods to detect pathogens which will then rapidly be adapted for specific food industry applications.

The bioterrorism imperative was very clearly identified in a report of the Institute of Food Technology, 'Food Research Trends 2003 and Beyond' (Mermelstein, 2002). In that report, 35 scientists responsible for peer review of research papers in IFT journals were given the role of 'soothsayers'. The great majority of those who commented on developments in food microbiology foreshadowed rapid advances in detection methods using descriptive terms such as nanobiotechnology, genomics, proteomics, biosensors, microarrays, faster, rapid and real-time detection. Thus the impediment of lack of 'timeliness' of microbiological analyses will receive close scrutiny. This is further emphasised by the theme of the January 2003 meeting of the Society for Applied Microbiology (UK), 'Lab on a chip: diagnosis and on-site testing'. In describing the content of that meeting, Coote (2002) noted that:

> The electronic chip, designed in the form of a biosensor, has opened up the possibility of comprehensive, simultaneous analysis for the presence of multiple pathogens or for parallel testing for the presence of specific drug resistance alleles. This multiplex system, when coupled to the miniaturisation of the chip components, has facilitated the development of portable hand-held devices for pathogen diagnoses in the clinical or environmental setting.

Such devices, with characteristics described as 'portability, speed and ease of detection, cost effectiveness and the need to fulfil the requirements of the end-user' appear to be ideally suited to satisfy the requirements listed by Betts (2002) for effective detection of foodborne pathogens.

Timeliness, in the accepted sense, is also an important factor contributing to the impact of a publication. A key objective of *Detecting Pathogens in Food* is to bring together leading researchers in their field to review the strengths and weaknesses of particular techniques and to put these into the context of food safety management systems and food safety regulation. Given advances in the last decade and projected developments, this volume is well timed to advise readers of the current status of detection methods and to provide an appreciation of the speed with which technological advances will open new vistas. One can anticipate the emergence of new methods not only delivering the traditional, non-negotiable outcomes of a standard method but also having a significant impact on currently intractable food safety issues that require resolution in a timely manner.

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