

# Practical Food Microbiology

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**THIRD EDITION**



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# Introduction

Eating habits in the western world today bear little resemblance to those of our grandparents and those who lived in the earlier part of the twentieth century. The science and technology of food production, processing and distribution has developed dramatically. With the aid of more rapid transport, by land, sea and air, an almost limitless range of food, in greater quantities than ever, from all over the world, is available from retail outlets for home preparation or 'eating out' at restaurants, fast food establishments and other food service premises. Less and less food is prepared now from fresh, locally produced basic ingredients as described in the older cookery books. Even when a basic recipe is used many of the ingredients will have been produced and processed in locations far from the place of final preparation, service and consumption.

This advancement in food availability and range, while it has satisfied the appetite of the consumer and introduced new tastes and eating experiences, has also been a cause of some concerns. These relate to whether the food is a benefit to the customer or whether it may be injurious to health. Consumers are concerned about both the nutritional composition of foods and the use of new ingredients and additives, new processes, and methods of packaging and storage that may result in a proliferation of microorganisms. The latter part of the twentieth century has seen an increase in the number of reports of food-borne illness, in the UK and other countries, that have been regarded by many as totally unacceptable. Vast quantities of food are consumed every day and the risk of illness or other adverse effects from contamination or inappropriate processing may be relatively small; even so, governments, such as that in the UK, have been forced to take action to improve food safety. In 2000 an independent food safety watchdog, the Food Standards Agency, was set up in the UK to protect the public's health and consumer interests in relation to food. The Agency has a number of targets which include: reduction of food-borne illness by 20% by improving food safety throughout the food chain; helping people to eat more healthily; making labelling more honest and informative; promoting best practice within the food industry; improving the enforcement of food law and earning people's trust by what they do and how they do it. Readers are directed to the Agency's website (see Appendix D) for further details on how they are proceeding. Subsequently a European Food Standards Agency has also been established.

For more than half a century the Public Health Laboratory Service (PHLS) has provided both microbiological advice and scientific expertise in the examination of food and water and the environment of their production. This service has been provided primarily for those who enforce the food law, the local and port health authorities and their environmental health departments and officers.

The scope of the laboratory work falls into a number of categories. An important element for the safeguarding of public health is the investigation of food that is a cause of complaint from a consumer, or in consequence of human illness attributed to the consumption of suspect food. Another public health function is the routine monitoring of food offered for sale as an independent check on the safety of food marketed within the territories of port health and local authorities. Routine monitoring or surveillance has in recent years received increasing attention because of the heightened awareness of the potential problems associated with food by the general public and official government bodies. Such routine testing increasingly incorporates planned surveillance of specific products deemed to present a potential risk or about which there is little documented information available. This surveillance can be initiated at a number of levels from the European Union (EU) through government departments or agencies, through local environmental health liaison groups to the PHLS as a whole or to a group of laboratories. The information gained from such planned surveillance is invaluable in the formulation of guidance to food producers and food law enforcers. The experience of the PHLS network of laboratories in providing a food, water and environmental service in England and Wales is not only wide ranging over almost every conceivable type of food, but also provides a foundation for the development and use of methodology appropriate to the needs of those charged with the promotion of health and protection from health risks associated with food.

The purpose of this manual is to assist those who are called upon to examine food or who seek to assess the findings of a microbiological examination of food. The majority of the methods described are used extensively in the PHLS, are published as PHLS standard operating procedures (SOPs) and form the basis of the methodology documented for accreditation of laboratories by the United Kingdom Accreditation Service (UKAS). Most methods are based on the corresponding standard methods produced by ISO/CEN/BSI. Laboratories are therefore examining food in a standard manner that is of value when the results are assessed in the context of risk to the consumer. This standard approach is also of importance in relation to the European single market. Official Control laboratories (those that examine food for the purposes of enforcing the food law) must be accredited, use standard methods and must also challenge their procedures by participation in a proficiency testing or external quality assessment scheme.

It is emphasized that the paramount objective in undertaking a food examination is to ensure that what the consumer eats is safe, or as safe as can be expected in the condition in which it is presented. The methods in this manual are appropriate for foods at point of consumption and it may be perceived that there is a bias towards the detection of pathogenic organisms or potential pathogens with lesser attention being given to the natural flora of the food material. Problems do arise from such microbial spoilage, but it rarely causes human illness. Visual inspection and observation of smell and taste will, in many instances, cause rejection of a food without recourse to microbiological examination.

The microbiological examination of food undertaken by food processors or manufacturers is usually performed for a reason entirely different to that of a laboratory that has a regulatory function. Food suppliers need to know that their products meet a specification that will ensure that the food will still be acceptable at the end of the expected shelf-life. The criteria used to assess food at production premises are more rigorous than those used to assess a ready-to-eat food at the point of sale. Apart from food that has received a sterilizing process in a sealed container, all other food undergoes microbial change over time. Such change is due to the normal ecology of living organisms that multiply, produce potentially toxic by-products and die at a rate that will depend on the environment. Temperature, water activity ( $a_w$ ), pH, availability of oxygen and of nutrients, and effects of different food ingredients or additives all determine the changes that occur in a food at any point in time. In the past, the approaches adopted by the quality controller in a food factory and the public health microbiologist investigating food in a possible food-borne incident were thought to have little bearing on each other. However, these spheres of activity have moved much closer together. Quality control is increasingly being required to demonstrate freedom from harmful organisms while the public health or clinical laboratory needs to be able to assess the whole range of microbial activity in a food in order to determine whether a pathogen can compete with and outgrow the natural flora.

Prepared cooked, chilled or frozen food is produced in such large quantities and is so widely distributed that the economic loss to the food industry in the event of a major food poisoning outbreak would be enormous. There would also be additional costs to the nation in lost working days and, in serious cases, medical care. Some legislation, such as the community controls imposed at EU level which have to be implemented into the domestic food law of member states, and also domestic legislation such as the UK Food Safety Act 1990, are designed to take into account international attitudes to food control. Early vertical EC Directives that are product-specific have included microbiological criteria that relate to the point of production. More recently there has been a move towards risk assessment and application of hazard analysis critical control point (HACCP) procedures, whereby the process is controlled by monitoring of specific critical processing points. Thus microbiological monitoring of the product is only required for verification purposes. Microbiological criteria suitable for products in international trade fall somewhere between those applicable at point of production and those applicable at the end of shelf-life. In order to give guidance on the interpretation of the results of examination of foods at point of sale, the PHLS has produced guidelines for ready-to-eat foods using the data accumulated from many years of routine monitoring and surveillance studies of such foods (see Section 2).

The aim of this manual is to act as a reference for the selection of suitable test methods for a number of types of food. The methods chosen can be performed in most food laboratories with readily available materials and equipment.

For further information the reader is referred to the bibliography in Appendix D, and for guidelines to the appendix to Section 2.

## **The structure of this manual**

This manual is structured to take the reader through the various steps in the microbiological examination of food. It begins by outlining why there is a need for such examination and the legislation, both from the EU and within the UK, which relates to the various food products (Sections 1 and 2). Section 3 discusses individual foods and the problems with which they are associated, then lists the tests relevant to their examination and the microbiological criteria available for particular food products.

Sections 4 to 6 give details on methods of sampling of foods and laboratory tests for enumeration, enrichment and isolation of food-borne microorganisms with particular mention of quality control and calculation of results. The microbiological methods relating to dairy products, eggs and shellfish are dealt with separately in Sections 7, 8 and 9 respectively. Legislation for dairy products lays down detailed methods for examination that are generally specific for that group of foods, thus a single section has been devoted to those methods. Similarly, the methods given in Section 8 for the examination of eggs, in-shell and bulk, are product-specific and differ in some respects from the general methods described in earlier sections. Section 9 is devoted to the examination of molluscan shellfish and includes details of sample preparation in addition to specific methods of examination. The more common biochemical tests necessary in the steps towards confirming the identity of organisms isolated from food are described in Section 10.

Supplementary information such as safety notes, procedural hints and worked examples, is included at various points in the methods in Sections 4–10. This information is highlighted in the text with boxes.

There are four appendices, A to D. Appendix A is a quick reference guide to the microbiological tests. The table provides a summary of the information provided in Sections 3, 7, 8 and 9, concerning the laboratory tests for specific foods. It serves as a rapid guide to the appropriate food heading and the type of test that should be considered. Once the food heading and range of tests have been identified then reference can be made to the more detailed information available elsewhere in this manual. In Section 3, which deals with schedules for the examination of foods, the tests have been divided into three groups: statutory, recommended and supplementary. These groups are identified in the quick reference guide by symbols for ease of recognition.

Appendix B discusses the steps to be taken in the examination of food from suspected food poisoning incidents with a brief summary of features of the most common agents. Appendix C lists UK reference facilities and PHLS EQA schemes, while Appendix D lists a number of useful texts on food microbiology and food safety and the website addresses of a number of organizations and agencies that can provide helpful information.

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# 1

## Indications for sampling and interpretation of results

- 1.1 Risk assessment and hazard analysis
- 1.2 Indications for sampling
- 1.3 Choice of method
- 1.4 Interpretation of results
- 1.5 The laboratory report
- 1.6 Criteria

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### 1.1 Risk assessment and hazard analysis

Almost all international food trade legislation is focused on assessing and managing risks from food. It is now a legal obligation in the European Union (EU) for food processors to identify any steps in their activities that are critical in ensuring food safety and to ensure that adequate safety procedures are implemented, maintained and reviewed [1]. The risk assessment of the food production process should identify and characterize the hazards in the process, assess the exposure and characterize the risks [2]. Hazard analysis critical control point (HACCP) principles should then be used to identify the critical control points to control the risks in order to form the basis of product safety management systems (Section 2). Sampling for microbiological testing is an important part of the risk assessment as it can be used to monitor the efficacy of the control systems but end product testing cannot be relied upon as a means of assuring food safety.

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### 1.2 Indications for sampling

Foods are sampled principally for the following reasons:

- Checks on hygienic production and handling techniques.
- Quality control and shelf-life performance.
- Suspicion of being the cause of food poisoning or as a result of consumer complaint.
- Verification of the quality of imported food.

Most quality control testing will be done by, or at the request of, the manufacturer whose interest is to demonstrate to the wholesaler, retailer or customer a quality product and, if possible, the product's superiority over competitors' products. With increasing need to label foods with a 'use-by' date, the setting of criteria to be satisfied throughout the declared shelf-life has become commonplace. Sampling for quality control purposes can be predetermined and structured in such a way that minor variations within batches of single products can

be detected quickly so that modification can be made before any noticeable change occurs that might alter consumer preference. In large manufacturing premises this might entail sampling at the beginning and end of a production run and at other times such as at the time of despatch from the factory and at the end of shelf-life under simulated retail conditions. Other food producers may adopt intermittent spot checks, while small producers are more likely to rely on process control without microbiological tests.

Independent checks on the hygienic production of a product and examination for evidence of poor storage and handling technique as part of the overall assessment of food placed on retail sale are desirable for further quality assurance and to help assure consumer safety. For these purposes, sampling needs to be targeted quite specifically if any useful data are to be collected. Organized surveys over limited time periods involving one specific product or type of product from certain types of shop or catering establishment and the use of a standard technique for examination will produce data that can be compared with those obtained in a similar manner elsewhere and on other occasions. Uniformity of approach is essential or wrong conclusions can be drawn. For example, results expressed as 'present' or 'absent' are of no value unless the quantity of food examined is stated. Numerical counts of colony forming units may vary quite considerably unless the dilution method, culture media and temperature of incubation employed on each occasion are the same. Checks on product hygiene and consumer acceptability can only properly be assessed with full possession of the product history. Food taken from shop display after in-house slicing and weighing may not be the same as that sampled whole and, within limits, the wider the range of organisms sought and quantified the better a food examiner can form an opinion about the food. Criteria used to assess a product at the end of shelf-life are often assumed to be applicable to the food 'as eaten', but storage conditions between purchase and consumption may also affect test results.

Sampling in cases of suspected food poisoning will be directed specifically at the food consumed by the complainant. Every effort should be made to sample the remains of the suspect food even if this means its retrieval from the refuse bin. Other food from the same meal, even if it is not the suspect ingredient, will be of next greatest value followed by other batches of food obtainable from the same catering establishment or supplier. If the causal food poisoning organism is known, examination can be limited to a search for that organism, thereby conserving laboratory resources. Further guidance is given in Appendix B.

Examination of food imported into the EU is performed to ensure that the food is of equivalent quality to food produced within the Union. When possible this is judged against criteria contained in EU legislation. In some instances, when a problem is identified in certain areas of the world, a commission decision will direct the examination of specific food items from those areas and the parameters to be tested.

In designing a sampling plan it is most important that all who are concerned with the collection and submission of the samples, the laboratory staff and

those who will be involved in interpretation of results, are consulted at an early stage. The objectives need to be clearly defined and understood to avoid wasted time and effort. There are limitations with all microbiological tests and these have to be taken into consideration before any action can be taken following a report from the laboratory. Many investigations involving pathogenic organisms will be concerned primarily with presence or absence of the organism in a defined amount of sample. This represents a 'two-class' plan, where in a given number of samples,  $n$ , a certain number will show the unacceptable presence of the test organism.

With some examinations for pathogenic organisms, and particularly in quality assessment studies where results are expressed in terms of colony counts, it is more usual to allow some latitude in results that marginally exceed the desired maximum count denoting satisfactory or acceptable limits and/or quality. In these instances it is appropriate to designate a permitted range that depends on the type of food and the situation. A full explanation of the principles and specific applications of sampling for microbiological analysis may be found in the publication of the International Commission on Microbiological Specifications for Foods (ICMSF) [3]. The sampling plan and tests may be selected as appropriate to the particular case or according to the circumstances related to the nature and treatment of the food that influence the potential hazards with which it is associated.

Where a rigid 'two-class' plan is not essential, use can be made of a 'three-class' plan that accepts a proportion of sample units whose test results fall between unequivocal acceptability and rejection. In devising a plan for a particular food it is necessary to set values for  $n$ ,  $m$ ,  $M$  and  $c$  where:

- $n$  is the number of sample units comprising the sample;
- $m$  is the threshold value for the number of bacteria; the result is considered satisfactory if the number of bacteria in all sample units does not exceed this value;
- $M$  is the maximum value for the number of bacteria; the result is considered unsatisfactory if the number of bacteria in one or more sample units is equal to or greater than this value;
- $c$  is the number of sample units where the bacterial count may be between  $m$  and  $M$ .
- The sample is considered acceptable if the bacterial counts of the other sample units are equal to or less than the value of  $m$ . For practical purposes,  $n$  is frequently given a value of five, and  $c$  a value of one or two.

Although there are some European Community (EC) directives that specify both standard and guideline criteria for certain foods, European legislation is now mainly focused on good manufacturing practice and the need for businesses to adopt HACCP principles to help ensure safe food production. Emphasis should be placed on the education of those who handle food as good hygiene is a prerequisite for safe food. The quality of basic food materials and scrupulous attention to hygiene and working practices are far more important than bacteriological checks on the processed food. Structured sampling for data collection

in support of HACCP systems is, however, a valuable tool when used in an informed manner.

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### **1.3 Choice of method**

Ideally, if microbiological criteria are included in food legislation or in a specification then the methods to be used for testing should be identified. The choice of method should be given careful consideration. Many of the organisms present in a food will be in a stressed condition as a result of the physical and chemical processes used in the production of that food. Freezing, drying, salting, pickling, sublethal heat treatment and extended chilling will all affect the recovery of target organisms. If the stressed organisms are then subjected to a harsh isolation protocol their recovery will be impaired and a falsely low result obtained. Some isolation methods take this into account and incorporate a resuscitation stage into the procedure. This is particularly important when attempting to recover pathogens such as *Salmonella*.

Preparation of the sample for examination should take into account the characteristics of the food product. If it is highly salted the concentration of the salt in the sample homogenate should be reduced to 2% or less to remove any inhibitory properties of the salt. Similarly if the product is highly acid or alkaline the pH of the homogenate may require adjustment to near neutrality to optimize recovery. Rehydration of dried products should be gradual to prevent the introduction of osmotic shock. These and other procedures can help maximize recovery of the target organisms from all foods examined.

Traditionally microorganisms in foods are enumerated by pour plate procedures, and these methods frequently form the basis of international standards. However these may not be ideal for recovery of stressed cells. If foods have been frozen or subjected to extensive chilling the temperature of the molten agar (c. 45°C) may result in further stress to the contaminating organisms. Many of the target organisms in foods either prefer or require aerobic conditions for growth. The restriction of oxygen in the depths of the agar in a plate may impede or prevent their growth. In the UK surface colony count methods are generally preferred for enumeration as they do not have these drawbacks and in addition have the convenience of being able to use pre-poured plates. However, surface methods of enumeration restrict the size of the inoculum and this may affect the limit of detection.

For certain organisms such as *Salmonella* that cause gastroenteritis their very presence in a food is significant. In addition, the levels present may be very low. In these cases it is necessary to use presence/absence procedures rather than relying on enumeration techniques for detection. Presence/absence procedures allow the examination of larger portions of sample, typically 25 g, by use of liquid enrichment procedures in nutrient and selective media formulated to optimize the recovery of the target organism in the presence of other naturally occurring food microflora.

It should be clear from the above that the method used for each target organ-



ism sought in a food should be tailored to maximize the likelihood of recovery of that organism. In this way the microbiologist can have confidence that if the target organism is not detected it is likely to be a true result.

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## **1.4** Interpretation of results

The interpretation of results in food microbiology is perhaps the most difficult and complex aspect of the examination process. Not only is it often impossible to make a definitive judgement owing to absence of supporting information but the precision and reproducibility of many microbiological tests may vary. Microorganisms in non-sterile food are in a dynamic environment in which multiplication and death of different species at differing rates means that the result of a test can only be valid for a single point in time. Colony counts alone can be misleading if bacterial growth has ceased whereas toxins already produced will persist. Staphylococcal enterotoxin survives the drying process in the manufacture of powdered milk and has caused confusion when reliance has been placed on culture results alone. It is sometimes not appreciated that homogeneity is rare in food and so the results obtained for one portion can be very different from those for another even if the samples have been taken in close proximity within the same batch. A variation in the viable counts of organisms will be apparent even in fluid foods such as soups and gravies if not homogenized in the laboratory before the test sample is taken. However, aerobic colony counts alone can be extremely valuable in the food manufacturing industry as the technique is straightforward and acceptance or rejection decisions can be made on variance from the norm for any one product when sampled regularly at the same point under the same conditions.

In regulatory control or hazard monitoring, colony counts obtained through random sampling can only form a small part of the overall assessment of the product. The number of pathogenic or potentially pathogenic organisms in a sample has a far greater significance but results depend on the food and the time at which it was sampled. Food that is sterilized in a can will remain sterile until the can is opened. Environmental contaminants may then be introduced and their numbers will vary according to the storage conditions, temperature and degree of handling both before the point of sale and after. Interpretation therefore requires cognizance both of the observed results and of the history of the food up to its receipt at the laboratory. Laboratory results alone make interpretation difficult unless the presence of an obligate pathogen such as *Salmonella* spp. has been demonstrated.

It is likely that the results of tests involving a search for indicator organisms such as members of the Enterobacteriaceae will only allow an informed judgement to be made, for example, about the adequacy of heat treatment or the level of post-processing contamination that has taken place. The presence of faecal organisms such as *Escherichia coli* means that either they have always been in the product or they have been acquired at a later stage during processing, handling or storage. Their presence indicates the need for further investigation. Their

absence gives some degree of assurance but cannot guarantee the absence of pathogens of faecal origin such as *Salmonella*. Even absence of target pathogens in tests specific for them only provides a degree of probability of absence in the whole batch of food (see ICMSF [3]). It is therefore essential that a food producer does not rely on end product testing alone but uses it in conjunction with good manufacturing practice and sound HACCP procedures.

Often the simplest approach is to proceed initially with definitive tests for specific pathogens. It is known that *Salmonella* infection is the commonest hazard in food of animal origin. It will certainly not be possible to subject a whole batch of the food to examination for this organism. A degree of assurance is only obtained when tests on uniform quantities of representative samples of the food by standard methods prove negative.

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## **1.5 The laboratory report**

The value of a laboratory report can, at best, only match the quality of the sample and the accompanying information. Comparisons can only be made between reports from different laboratories or on different occasions if the reporting methods are standardized. A standardized report form assists in this respect. The report should include a description of the food itself and observations on the physical condition of the sample. The results of general and indicator tests and those concerning specific organisms should relate to a specified mass or volume of the food. For the majority of quantitative tests it is convenient to relate the presence or absence of the organism sought to 1 g or 1 mL of test sample even if the actual quantity examined is different. Knowledge of the precise quantity of test sample is essential for calculating colony counts.

When interpretation of a laboratory report is required for referee purposes, such as in a court of law, it is vital that the documentation provides an uninterrupted record of the progress of the sample through the laboratory. The qualifications, status and role of recognized food examiners in the UK have now been established [4]. In order to ensure the continuity of evidence, the following documents and information should be available:

- The date, time and place of sampling recorded by the sampling officer.
- Verification of the custody of the sample during transit to the laboratory and the conditions of storage during transport.
- Signatures that acknowledge transfer of the sample to a member of the laboratory staff.
- Records of conditions of storage in the laboratory.
- Records of the members of staff performing all the stages of testing and the conditions prevailing during the tests.
- Records of all results obtained and how they were derived.
- The certificate of examination issued by the food examiner based on this accurate laboratory documentation.

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## 1.6 Criteria

Before a sampling programme is embarked upon the criteria to be adopted in the interpretation of the results need to be agreed between the parties concerned. This avoids a great deal of useless investigation and wasted financial outlay. For these reasons it is not possible to give criteria that are applicable in all situations. Each investigation needs its own assessment by qualified and experienced personnel. The interpretation of statutory tests with 'pass' or 'fail' end point criteria has to be undertaken with care since microorganisms are living entities that cannot be assessed in finite terms in the way that chemical analysis allows.

In 1992 the Public Health Laboratory Service (PHLS) published guidelines for microbiological acceptability of some ready-to-eat foods [5]. This was in response to requests from Environmental Health Officers, consumer organizations and government agencies for help in the furtherance of improving knowledge about the safety of food. Apart from setting proscriptive limits for certain pathogens, the guidelines recommend ranges of bacterial colony counts for a number of different types of food which allow the division of results into four different levels of quality. These range from 'satisfactory' quality to 'unacceptable, potentially hazardous' quality. The guidelines have no formal status and refer only to 'ready-to-eat' food sampled at point of sale, but they do reflect the opinions of experienced workers with access to a wealth of published and unpublished data collected over half a century by the PHLS. These guidelines have been updated and expanded twice since 1992 on the basis of comments received from microbiologists and Environmental Health Officers and accumulation of further data derived from routine samples and targeted, structured surveys. Modification and extension of their scope is made periodically in response to any suggestions or criticism. The PHLS guidelines current at the time of publication of this manual are summarized in Section 2.

The Institute of Food Science and Technology has also published microbiological criteria [6] that are applicable to a wide range of foods. These criteria adopt a two-tier approach, the levels expected as a result of good manufacturing practice and the maximum levels that are acceptable at any point in the shelf-life of a food.

In food microbiology there is no rule of thumb that provides an interpretation in all circumstances. Each food must be considered individually taking into account all the relevant factors including the ingredients, process, type of packaging, conditions of storage and the likely remaining shelf-life.

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## 1.7 References

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- 2 Mitchell RT. *Practical Microbiological Risk Analysis*. Oxford: Chandos Publishing Ltd, 2000.

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- 4 Great Britain. *Statutory Instrument 1990 No. 2463. The Food Safety (Sampling and Qualifications) Regulations 1990*. London: HMSO, 1990.
- 5 Gilbert RJ. Provisional microbiological guidelines for some ready-to-eat foods sampled at point of sale: notes for PHLS Food Examiners. *PHLS Microbiol Dig* 1992; **9**: 98–9.
- 6 Bell C, Greenwood M, Hooker J, Kyriakides A, Mills R. *Development and Use of Microbiological Criteria for Foods*. London: Institute of Food Science and Technology, 1999.

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## 2

# Legislation, codes of practice and microbiological criteria

- 2.1 UK legislation: the Food Safety Act 1990
- 2.2 European Community legislation
- 2.3 Hazard analysis
- 2.4 Laboratory accreditation
- 2.5 Microbiological criteria
- 2.6 Microbiological guidelines for some ready-to-eat foods sampled at point of sale
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### 2.1 UK legislation: the Food Safety Act 1990

The Food Safety Act, the main provisions of which came into effect on 1 January 1991, provides the basic framework for all food legislation throughout the UK. Its primary aim is to strengthen and update the previous food legislation to achieve the highest possible standards of food safety and consumer protection throughout the food chain. The main feature of the Act is the number of enabling powers that it contains. This allows ministers to make further regulations to implement food safety measures and to produce codes of practice to bring about more consistent standards of enforcement. Food is broadly defined under the Act to include virtually anything that is eaten, drunk or sold as a food product; the definition also includes water, which was not covered under previous food legislation.

There were a number of reasons why a new Food Safety Act was required [1]:

- Existing legislation, which had been consolidated in the Food Act 1984, but not fully revised since 1938, had not kept pace with the rapid advances in food technology, and changes in eating habits and shopping patterns.
- There were gaps in the existing legislation.
- The major changes of approach to food law brought about by the European Community (EC) harmonization programme required a change in the UK food law to make the implementation of EC legislation easier.
- The considerable concern in the late 1980s within the government and the general public about the increasing incidence of food-borne infection, particularly associated with *Campylobacter* spp., *Salmonella* spp. (especially *S. Enteritidis* phage type 4) and *Listeria monocytogenes*.

Some features of the Act in relation to food microbiology are as follows.

## **Section 8 Selling food not complying with food safety requirements**

### **Paragraph (2)**

This key provision of the Act makes it an offence to sell food that does not comply with food safety requirements. Food fails to comply if:

- it has been rendered injurious to health;
- it is unfit for human consumption; or
- it is so contaminated, whether by extraneous matter or otherwise, that it would not be reasonable to expect it to be used for human consumption in that state. This would, for example, include food being affected by mould that does not necessarily make it injurious or unfit.

The element of 'contamination' was not included in previous legislation, under which possession of contaminated food was not an offence unless it was sold to the purchaser's prejudice; that is, the food was not of the nature, substance and quality demanded. Contamination therefore will permit prosecutions to be brought solely on the results of the microbiological examination or chemical analysis of food.

### **Paragraph (3)**

Under previous legislation it was difficult to deal with a batch of food that was believed to be unfit. Under the present Act if any part of a batch of food fails to comply with food safety requirements, then the whole batch will be presumed not to comply until the contrary is proved. This power mirrors the policy of reputable manufacturers to withdraw an entire consignment if some products are found to be contaminated.

## **Section 9(2 & 4) Detention of suspect food**

The powers to inspect and seize food are largely the same as under previous legislation except that authorized officers may detain food for 21 days to allow microbiological examination or chemical analysis to be performed to establish whether it complies with food safety requirements. These powers also apply to food that is thought 'likely to cause food poisoning or any disease communicable to humans'.

## **Section 13 Emergency control orders**

This section provides ministers with the power to issue emergency control orders to prohibit the sale of food where there is an imminent risk of injury to health. This power will be used where voluntary procedures, following the issue of food hazard warnings, are unlikely to be effective, for example the sale of a widely distributed contaminated canned food.

## **Section 16(1b) Provision for microbiological standards**

Provision may be made by regulations for securing that food is fit for human consumption and meets such microbiological standards (whether going to the fitness of food or otherwise) as may be specified by or under the regulations. This allows for the introduction of mandatory microbiological standards for specified foods.

## **Section 17(1) Enforcement of Community provisions**

This section provides ministers the power, by regulations, to make such provision with respect to food, food sources or contact materials as appears to them to be called for by any EC obligation. This will permit the enforcement of any Community provisions for microbiological standards for foods.

## **Section 28(2) Food examiners**

The Act recognizes the role of the food examiner to perform the new statutory function of microbiological examination of food. In this task the role of the food examiner will correspond to that of the public analyst who has a long-standing remit to carry out statutory analysis (chemical) of food samples. Food examiners therefore are the individuals to whom an enforcement officer is required to submit any sample taken for enforcement purposes (i.e. where it may be introduced as evidence in any court proceedings under the Act) if the officer considers the sample should undergo microbiological examination. The purpose of this legislation is to ensure that the microbiological examination of food is carried out to a high standard and (by specifying their necessary qualifications) to ensure that the competence of food examiners when asked to give an expert view during legal proceedings against a food producer/retailer is not open to question.

Qualifications for food examiners are prescribed in the Food Safety (Sampling and Qualifications) Regulations 1990, which came into force on 1 January 1991. There is no single qualification to denote the requisite academic attainment and practical experience of a food examiner, and the regulations allow a wide range of academic or professional qualification in conjunction with 3 years relevant experience. An important element of the Regulations is the provision of certificates by examiners relating to the microbiological results of examination of samples submitted to them. Food examiners are expected to provide written opinion and observation, if deemed appropriate, on the safety and quality of food samples submitted to their laboratories for examination under the Regulations. The certificates are legal documents and can be used as evidence in legal proceedings.

## Section 40 Codes of practice

Ministers may issue codes of practice to guide food authorities on the execution and enforcement of the Act and subsequent legislation made under it. The objective of issuing codes of practice is to ensure more even and consistent standards of enforcement across the UK. These documents are not legally binding but food authorities will be required to have regard to the guidance contained in them. However, ministers will be able to issue directions requiring food authorities to take specific action in order to conform with a code of practice and these directions will be enforceable through the courts.

Twenty codes of practice have been issued to date, some of which have been or are being updated and amended [2]. Code of Practice No. 7 (Sampling for Analysis or Examination) is of particular importance to food examiners as it gives guidance to enforcement officers for taking samples, and should help to ensure that adequate and appropriate samples are submitted for examination. Code of Practice No. 7 has recently been revised to take account of experience gained in practice.

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### **2.2** European Community legislation

Food hygiene and food safety legislation can no longer be viewed in an exclusively national context, it is an EC-wide issue. The EC has been involved in food legislation since 1964. The pace of its development and implementation accelerated in the period to the end of 1992 prior to the completion of the single European market. However, EC food law in the run-up to the establishment of the single market in 1992 was still essentially concentrated on questions of trade and free movement of goods. Following the bovine spongiform encephalopathy (BSE) crisis the European Parliament reformed the Commission's structures for preparing food legislation and published a Green Paper on Food Law (COM(97)176) in May 1997. Its main thrust is ensuring the protection of consumers and public health and the free circulation of goods within the Single Market. The Green Paper identified six principles of EC food policy; proposed the general application of hazard analysis critical control point (HACCP) principles to all products; put forward the proposal that primary agricultural products should be included within the Product Liability Directive (85/374/EEC); and ensured that all EC laws are compatible with the new international obligations of the European Union under the World Trade Organization (WTO) Sanitary and Phytosanitary and Technical Barriers to Trade Agreements. By the end of 1997, food law issues had become such a priority that heads of government and states at their twice-yearly European Summits agreed to a Declaration on Food Safety at Luxembourg on 12–13 December 1997 [3]. In 1999, Directive 99/34/EC amended the Product Liability Directive (85/374/EEC) in that primary agricultural products are no longer exempt so as to restore consumer confidence in the safety of such products.



On 12 January 2000 the European Commission adopted a White Paper on Food Safety [4]. The Commission stated in this document that the most appropriate response to guarantee the highest EC food safety standards is the establishment of an independent European Food Authority. The White Paper also includes a comprehensive range of over 80 areas where European food law needs to be amended and improved. The new legal frame-work will cover animal feed, animal health and welfare, hygiene, contaminants and residues, novel food, additives, flavourings, packaging and irradiation. In November 2000 the European Commission put forward a proposal for a Regulation laying down the general principles of food law and establishing the European Food Authority. The European Parliament (EP) approved the creation of an independent European Food Safety Authority (EFSA) in a final agreement on 11 December 2001 so that the EFSA can start operating in the first half of 2002. 'Safety' has been added to the title of the new body through an amendment adopted by the EP. On 21 January 2001, the EFSA became a reality when the Council of Ministers adopted the key legislation that provides the legal basis for establishing the EFSA and general principles and requirements for EU food law (Regulation 2002/178/EC) [5]. The General Food Law Regulation 2002/178/EC embodies the responsibilities and obligations to be placed upon all operators in the food chain from farmers to retailers.

The EFSA will have a broad mandate, including a wide range of scientific and technical support tasks on all matters having a direct or indirect impact on food safety. The EFSA's mission therefore includes the provision of scientific opinions on all issues in relation to animal health and welfare, plant health and genetically modified organisms, without prejudice to the competence conferred to the Agency for the Evaluation for Medicinal Products (EMA). The EFSA will also have a major task in informing the public about its activities.

## Types of EC legislation

The three types of legislation within the EC are [6]:

- **Regulation.** A legal act which has general applications and is binding in its entirety and directly applicable to the citizens, courts and governments of all Member States. Regulations do not therefore have to be transferred into domestic laws and are chiefly designed to ensure uniformity of law across the Community.
- **Directive.** A binding law directed to one or more Member States. The law states objectives that the Member State(s) are required to confirm within a specified time. A directive has to be implemented by Member States by amendment of their domestic laws to comply with the stated objectives; in the UK this is being done in the form of new statutory instruments under the Food Safety Act. This process is known as 'approximation of laws' or 'harmonization' since it involves the alignment of domestic policy throughout the Community.

- **Decision.** An act which is directed at specific individuals, companies or Member States which is binding in its entirety. Decisions addressed to Member States are directly applicable in the same way as directives.

The 1985 European Commission White Paper 'Completing the Internal Market' catalogued the measures necessary to allow for the free movement of goods (including foods, services, capital and labour) which would lead to the removal of all physical, technical and fiscal barriers between Member States. Since 1 January 1993, food has moved freely within the EC with the minimum of inspection at land or sea frontiers. Harmonized rules have been adopted, applicable to all food produced in the EC, underpinned by the principle of mutual recognition of national standards and regulations for matters that do not require EC legislation [7]. Specific directives are in place for minced meat and meat preparations, live bivalve molluscs, fishery products, milk and milk products, and egg products and for the hygiene of foodstuffs. Foods entering the EC from countries outside (third countries) will be subject to EC hygiene standards. Products of animal origin will undergo a rigorous inspection on entering the EC.

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## **2.3 Hazard analysis**

There is growing acceptance throughout the EU and in many other countries of the value of HACCP principles in ensuring the microbiological safety of foods. The HACCP approach [8] is a systematic way of analysing the potential hazards of a food operation, identifying the points in the operation where the hazards may occur, and where controls over those that are important to consumer safety can be achieved. Most of the product-specific EC directives as well as the Directive on the Hygiene of Foodstuffs (93/43/EEC), place obligations on industry and food business operators to adopt HACCP principles as the basis for their product safety management systems. The advantages of the HACCP approach over a food safety control system based purely on microbiological standards is now widely recognized. Thus, the Commission proposes to consolidate and simplify existing EC food hygiene legislation [4,9]. These are expected to be implemented by 2004. The proposed consolidation adopts a unified approach to hygiene and extends the general hygiene rules and HACCP principles to cover hygiene throughout the food chain, including primary production, i.e. the 'farm-to-fork' approach to managing food safety. Responsibility of food safety will be unambiguously placed onto food producers. A fully documented HACCP plan will be required of all food producers, including caterers, regardless of size. This will include a specific monitoring programme, thereby reinforcing the own-check principle of food producers. An absolute requirement for full traceability of all foods and ingredients used in food production is also introduced, such that all food producers must keep adequate records to allow full traceability throughout the products' allotted shelf-life.

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## 2.4 Laboratory accreditation

The mutual recognition of microbiological results obtained by different control bodies is an essential precondition to unrestricted trade in food between the Member States. Since 1 November 1998, under the terms of the Official Control of Foodstuffs Directive (89/397/EEC) and the Additional Measures Food Control Directive (93/99/EC), only Official Food Control Laboratories are allowed to examine Official Control Samples. These laboratories are accredited by their national accreditation organization according to the Euronorm (EN 45001) series of standards. The directives also require that such laboratories participate in a proficiency testing scheme. In the UK this means accreditation by the United Kingdom Accreditation Service (UKAS), and participation in a food microbiology quality assessment (proficiency testing) scheme, such as that introduced by the Public Health Laboratory Service (PHLS) in September 1991 [10]. Since this legislation was adopted the standard to which laboratories must be accredited has been changed to ISO/IEC 17025 [11].

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## 2.5 Microbiological criteria

Several international organizations are concerned with the establishment and application of microbiological criteria for foods; these include the EU, the World Health Organization (WHO), the International Commission on Microbiological Specifications for Foods (ICMSF) and the Codex Alimentarius Commission. The purpose of establishing these criteria is to protect the health of the consumer by providing safe, sound and wholesome products, and to meet the requirements of fair practices in trade. The mere existence of criteria cannot protect consumer health *per se*; of equal, or greater, importance is the use of good manufacturing practice to ensure that undesirable organisms are eliminated as far as is practicable. Microbiological criteria can be divided under the headings:

- **Microbiological standards.** Mandatory criteria that are included in legislation or regulations; failure to comply with these can result in prosecution.
- **Microbiological specifications.** Generally contractual agreements between a manufacturer and a purchaser to check that foods are of the required quality.
- **Microbiological guidelines.** Non-mandatory criteria usually intended to guide the manufacturer and help to ensure good hygienic practice.

Ideally, any microbiological criterion for a food should include the following information:

- a statement of the microorganisms and/or toxins of concern;
- laboratory methods for their detection and quantification;
- the sampling plan;
- the microbiological limits; and
- the number of samples required to conform to these limits.

Some EC directives, e.g. those for milk and milk-based products and for fishery products, contain a mixture of mandatory (microbiological standards) and non-mandatory criteria (guidelines).

In theory, EC-based microbiological standards would provide common criteria against which the safety of food could be measured consistently. However, some Member States, including the UK, have adopted a cautious approach to defining and agreeing specific standards for particular types of foods. Currently few directives have specified microbiological standards but other directives have provisions for standards to be agreed at a later date, or where standards have been set there is scope for them to be revised. Future EU legislation may specify both microbiological criteria and the laboratory methods to be employed for checking compliance with the criteria.

The following directives include microbiological standards:

- Egg Products Directive 89/437/EEC, as amended by Directive 89/662/EEC and Directive 91/684/EEC (see Sections 3 and 8).
- Live Bivalve Molluscs Directive 91/492/EEC, as amended by Directive 97/61/EC (see Sections 3 and 9).
- Fishery Products Directive 91/493/EEC, as amended by Directive 95/71/EC and Commission Decision 93/51/EEC on the microbiological criteria applicable to the production of cooked crustaceans and molluscan shellfish (see Sections 3 and 9).
- Milk and Milk-based Products Directive 92/46/EEC (see Sections 3 and 7).
- Minced Meat and Meat Preparations Directive 94/65/EC (see Section 3).

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## **2.6 Microbiological guidelines for some ready-to-eat foods sampled at point of sale**

In the past, Environmental Health Officers frequently sought advice from their local public health laboratory on the significance of the microbiological results of food samples they had submitted for examination. In the absence of microbiological standards (UK or EC) or published guidelines for many types of foods such interpretation has had to be based on personal experience of results from a large number of such foods examined over many years. While there is no reason to doubt the soundness of such advice in the past, the need to complete formal certificates within the new legal framework suggested that structured guidance would assist those designated as food examiners within the PHLS to fulfil their obligations.

In 2000 the PHLS published the second revised guidelines on the interpretation of the results from the microbiological examination of various ready-to-eat foods sampled at point of sale (Tables 2.1 & 2.2) [12]. The guidelines were expanded to take account of experience gained of their value in practice and additional information that has become available. They are not statutory microbiological standards; they only reflect the opinion of the PHLS Advisory Committee on Food and Dairy Products and are subject to periodic revision as

**Table 2.1** PHLS Guidelines for the microbiological quality of various ready-to-eat foods. Reproduced with permission of the PHLS Communicable Disease Surveillance Centre © PHLS [12].

Food category (see Table 2.2)	Criterion	Microbiological quality (cfu/g unless stated)			Unacceptable/potentially hazardous
		Satisfactory	Acceptable	Unsatisfactory	
	<b>Aerobic colony count* 30°C/4 h</b>				
1		<10 <sup>3</sup>	10 <sup>3</sup> –<10 <sup>4</sup>	≥10 <sup>4</sup>	N/A†**
2		<10 <sup>4</sup>	10 <sup>4</sup> –<10 <sup>5</sup>	≥10 <sup>5</sup>	N/A**
3		<10 <sup>5</sup>	10 <sup>5</sup> –<10 <sup>6</sup>	≥10 <sup>6</sup>	N/A**
4		<10 <sup>6</sup>	10 <sup>6</sup> –<10 <sup>7</sup>	≥10 <sup>7</sup>	N/A**
5		N/A	N/A	N/A	N/A**
	<b>Indicator organisms††</b>				
1–5	Enterobacteriaceae‡	<100	100–<10 <sup>4</sup>	≥10 <sup>4</sup>	N/A**
1–5	<i>Escherichia coli</i> (total)	<20	20–<100	≥100	N/A**
1–5	<i>Listeria</i> spp. (total)	<20	20–<100	≥100	N/A**
	<b>Pathogens</b>				
1–5	<i>Salmonella</i> spp.	ND			D
1–5	<i>Campylobacter</i> spp.	ND			D
1–5	<i>E. coli</i> O157 & other VTEC	ND			D
1–5	<i>Vibrio cholerae</i>	ND			D
1–5	<i>Vibrio parahaemolyticus</i> §	<20	20–<100	100–<10 <sup>3</sup>	≥10 <sup>3</sup>
1–5	<i>Listeria monocytogenes</i>	<20¶	20–<100	N/A	≥100
1–5	<i>Staphylococcus aureus</i>	<20	20–<100	100–<10 <sup>4</sup>	≥10 <sup>4</sup>
1–5	<i>Clostridium perfringens</i>	<20	20–<100	100–<10 <sup>4</sup>	≥10 <sup>4</sup>
1–5	<i>Bacillus cereus</i> and other pathogenic <i>Bacillus</i> spp.	<10 <sup>3</sup>	10 <sup>3</sup> –<10 <sup>4</sup>	10 <sup>4</sup> –<10 <sup>5</sup>	≥10 <sup>5</sup>

cfu, colony forming units; VTEC, verocytotoxin producing *E. coli*. D, detected in 25 g; ND, not detected in 25 g.

\*Guidelines for aerobic colony counts may not apply to certain fermented foods, e.g. salami, soft cheese and unpasteurized yoghurt. These foods fall into Category 5. Acceptability is based on appearance, smell, texture and the levels or absence of indicator organisms or pathogens.

†N/A denotes not applicable.

‡Not applicable to fresh fruit, vegetables and salad vegetables.

§Relevant to seafoods only.

||If the *Bacillus* counts exceed 10<sup>4</sup> cfu/g, the organism should be identified.

¶Not detected in 25 g for certain long shelf-life products under refrigeration.

\*\*Prosecution based solely on high colony counts and/or indicator organisms in the absence of other criteria of unacceptability is unlikely to be successful.

††On occasions some strains may be pathogenic.

**Table 2.2** Colony count categories for different types of ready-to-eat foods. Reproduced with permission of the PHLS Communicable Disease Surveillance Centre © PHLS [12].

Food group	Product	Category
Meat	Beefburgers	1
	Brawn	4
	Faggots	2
	Ham: raw (Parma/country style)	5
	Kebabs	2
	Meat meals (shepherds/cottage pie, casseroles)	2
	Meat pies (steak and kidney, pasty)	1
	Meat, sliced (cooked ham, tongue)	4
	Meat, sliced (beef, haslet, pork, poultry, etc.)	3
	Pork pies	1
	Poultry (unsliced)	2
	Salami and fermented meat products	5
	Sausages (British)	2
	Sausages (smoked)	5
	Sausage roll	1
	Scotch egg	1
	Tripe and other offal	4
Seafood	Crustaceans (crab, lobster, prawns)	3
	Herring/roll mop and other raw pickled fish	1
	Other fish (cooked)	3
	Seafood meals	3
	Molluscs and other shellfish (cooked)	4
	Smoked fish	4
Dessert	Taramasalata	4
	Cakes, pastries, slices and desserts — with dairy cream	3
	Cakes, pastries, slices and desserts — without dairy cream	2
	Cheesecake	5
	Mousse/dessert	1
	Tarts, flans and pies	2
Savoury	Trifle	3
	Bean curd	5
	Bhaji (onion, spinach, vegetable)	1
	Cheese-based bakery products	2
	Fermented foods	5
	Flan/quiche	2
	Hummus, tzatziki and other dips	4
	Mayonnaise/dressings	2
	Paté (meat, seafood or vegetable)	3
	Samosa	2
	Satay	3
Vegetable	Spring rolls	3
	Coleslaw	3
	Fruit and vegetables (dried)	3
	Fruit and vegetables (fresh)	5

**Table 2.2** *continued.*

Food group	Product	Category
	Prepared mixed salads and crudités	4
	Rice	3
	Vegetables and vegetable meals (cooked)	2
Dairy	Cheese	5
	Ice-cream, milk shakes (non-dairy)	2
	Ice-lollipops, slush and sorbet	2
	Yoghurt/frozen yoghurt (natural)	5
Ready-to-eat meals	Pasta/pizza	2
	Meals (other)	2
Sandwiches and filled rolls	With salad	5
	Without salad	4
	With cheese	5

additional information becomes available. The guidelines have no formal standing or status, but:

- samples falling in the ‘unsatisfactory’ category indicate that further sampling may be necessary and that Environmental Health Officers may wish to undertake a detailed inspection of the premises, food production and handling processes, etc.;
- samples falling in the ‘unacceptable, potentially hazardous’ category might form a basis for prosecution by the Environmental Health Department.

Careful consideration should be given to the likelihood of success when embarking on a prosecution based solely on unsatisfactory levels in the absence of other unacceptable criteria. PHLS food examiners draw on their own experience and expertise in determining the advice and comments they wish to give and are required to do this when asked to give an expert opinion during legal proceedings. Provision has been made for the inclusion of microbiological standards for foods in both the Food Safety Act 1990 and in EC legislation. Although mandatory standards for more ready-to-eat foods would simplify the interpretation of results, it is preferable to concentrate resources on implementing good manufacturing practice coupled with HACCP principles and risk assessment than to increase end product testing to ensure conformity with microbiological criteria.

Other UK publications containing microbiological guidelines issued by professional and trade organizations representing the food industry are listed in the appendix below.

In fact food microbiologists are concerned with the practical implications of the microflora of the food and the food microorganisms that can cause spoilage of food and disease in humans. The primary tool of microbiologists is the ability to identify and quantitate food-borne microorganisms. [www.AgriMoon.Com](http://www.AgriMoon.Com) FOOD AND INDUSTRIAL MICROBIOLOGY pyorubin (red-brown). *P. aeruginosa* is often preliminarily identified by its fluorescence and grape-like or tortilla-like odor in vitro. New & Forthcoming Titles | The Practical Food Microbiology Series. New & Forthcoming Titles. Home > New & Forthcoming Titles. *Listeria*. A practical approach to the organism and its control in foods. Series: The Practical Food Microbiology Series. Bell, Chris, Kyriakides, Alex 1998. Price from 53,49 €,-.